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EXECUTIVE SUMMARY

OAST Summer Workshop

NASA GRANT
NSG 1186

OAST ODU 1975

National Aeronautics
and Space Administration
Office of Aeronautics and Space
Technology and Old Dominion University

NOTICE

The results of the OAST Space Technology Workshop which was held at Madison College, Harrisonburg, Virginia, August 3 - 15, 1975 are contained in the following reports:

EXECUTIVE SUMMARY

VOL I DATA PROCESSING AND TRANSFER

VOL II SENSING AND DATA ACQUISITION

VOL III NAVIGATION, GUIDANCE, AND CONTROL

VOL IV POWER

VOL V PROPULSION

VOL VI STRUCTURE AND DYNAMICS

VOL VII MATERIALS

VOL VIII THERMAL CONTROL

VOL IX ENTRY

VOL X BASIC RESEARCH

VOL XI LIFE SUPPORT

Copies of these reports may be obtained by contacting:

NASA - LANGLEY RESEARCH CENTER

ATTN: 418/CHARLES I. TYNAN, JR.

HAMPTON, VA. 23665

COMMERCIAL TELEPHONE: 804/827-3666

FEDERAL TELECOMMUNICATIONS SYSTEM: 928-3666

NASA

Office of Aeronautics and Space Technology

Summer Workshop

August 3 through 16, 1975

Conducted at Madison College, Harrisonburg, Virginia

Executive Summary

This executive summary and the eleven discipline technology reports Volumes I through XI constitutes the final report for NASA Grant NSG 1186.

EDITORS:

C. I. TYNAN, JR.
SHUTTLE EXPERIMENTS OFFICE
NASA-LANGLEY RESEARCH CENTER

C. BROOKS
ASSISTANT PROFESSOR OF ENGLISH
OLD DOMINION UNIVERSITY

G. GOGLIA
PROFESSOR AND CHAIRMAN
MECHANICAL ENGINEERING
& MECHANICS DEPT.
OLD DOMINION UNIVERSITY

OAST Space Technology Workshop
EXECUTIVE SUMMARY

R. E. Smylie
CHAIRMAN, STEERING COMMITTEE
OAST-NASA HEADQUARTERS

MEMBERS:

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J. LAZAR	OAST
D. C. POPMA	OSF
S. R. SADIN	OAST
F. C. SCHWENE	OAST

COLLABORATOR:

GENE L. GOGLIA
PROFESSOR AND CHAIRMAN
MECHANICAL ENGINEERING
& MECHANICS
OLD DOMINION UNIVERSITY

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FOREWORD

OAST's major goal is to provide a technology base which will adequately support current and future space activities involving the exploration and exploitation of space. We in OAST have felt for some time that a more effective mechanism was needed to get the technology users and technology generators to jointly review and discuss technology requirements, as well as implement the transfer of advanced technology to flight projects. In order to facilitate this process in "real time," we organized the OAST Space Technology Workshop.

About 150 of NASA's best researchers and technologists were assembled for this Workshop. From input presentations and documentation and day-to-day conferences with our "users," i.e., representatives of the Offices of Applications, Space Flight, and Space Sciences, we extracted both the technology needs to support projected missions and the opportunities afforded for experimentation in the space environment.

The Workshop accomplished two primary objectives: (1) we formulated technology needs which addressed recommendations from our users, early drafts of the "Outlook for Space," and other sources; and (2) we defined shuttle flight experiments and payloads which would enhance bringing those technologies to a satisfactory state of readiness. Approximately 200 space experiments or payloads were identified in 11 technological areas.

Results of the Workshop are being reported to universities, industry, and other Government agencies to initiate a dialogue, obtain feedback, and develop a partnership that will take advantage of the engineering and technology needs and opportunities of the future. Our ultimate goal is to enable a broad group of engineering users to perform research and technology experiments in space by utilizing the Space Transportation System.

This intensive 2-week effort provided the opportunity to discuss technology gaps, overlap between disciplines, and interdisciplinary goals. The participants profited from hearing invited speakers and the dialogue between technology "developers" and "users" was highly beneficial. The initiative, enthusiasm and technical expertise contributed by the participants were recognized and are warmly appreciated.

The Steering Committee wishes to acknowledge the excellent administrative, technical, and logistics support provided by the Langley Research Center and Old Dominion University which included Workshop planning, preparation of input data packages, on-site accommodations, and report compilation and publication.

R.E. Smylie

R.E. Smylie, Chairman
Steering Committee

INTRODUCTION

Within NASA, the Offices of Applications (OA), Space Flight (OSF), Space Science (OSS) and Tracking and Data Acquisition (OTDA) are responsible for operational systems and missions in space. With regard to space activities, these offices are NASA's prime interface with the benefitting organizations which include other Government agencies, industry and educational and research institutions, as well as individual researchers. The Office of Aeronautics and Space Technology (OAST) is responsible for providing the advanced technology to meet the needs of these other offices.

The major goal is to provide a technology base which will adequately support current and future space activities involving the exploration and exploitation of space. The program concentrates on advancing the technologies used in systems required to support, protect, power, control and communicate with the various spacecraft needed to achieve the objectives of current and future NASA space missions. Much of the basic technology being developed in the program is also applicable to the solutions of a broad range of terrestrial problems in fields such as energy and communications.

The Workshop, held in August in Madison College in Harrisonburg, Virginia, was designed to aid in the future development and planning of OAST's overall space technology program. The Workshop was the outgrowth of a recommendation made to OAST by the National Research Council/Aeronautics and Space Engineering Board in December 1974 as well as OAST's desire to find better utilization of newly developed space technologies.

It is hoped that the Workshop outputs will provide a sound technical basis for the overall planning and implementation of OAST's disciplinary technology programs, add new dimensions to its basic research program and establish technology experiment flight programs for those technology areas requiring readiness demonstrations.

One of the major products of the Workshop was the preliminary definition of the research and technology investigations which require or which could significantly benefit from an in-space experiment, systems demonstration or component test using the Space Transportation System (shuttle, Spacelab, and upper stages) which is currently being developed and will begin operations in the 1979-80 time frame. Approximately 200 space experiments or payloads were identified which met one or more of the recommendations in the "Outlook for Space" study. About one-third of these experiments are "new", i.e., identified for the first time at the Workshop. Essentially all of these experiments are traceable, through technology requirements, to candidate OAST major thrusts which were synthesized during the Workshop. The major thrusts are in turn responsive to the themes, objectives and systems identified in "Outlook for Space". Although this forum did not permit an exhaustive treatment of user needs, a significant interchange among users, disciplines and basic research did occur.

This document provides an overview of the implementation aspects of the Workshop as well as synopses of the eleven discipline technology reports which emanated from the Workshop.

I. Objectives

The specific objectives of the effort were:

Planning:

Formulate technology needs that reflect recommendations from the "Outlook for Space" and other pertinent sources.

Incorporate needs into structured technology goals and objectives

Experiment/Payload Identification:

Identify areas where experimentation in space could significantly enhance technology development

Identify specific space experiments which would utilize the research facilities made possible by the Space Transportation Systems (STS)

II. Approach/Logic Flow

The products from this Workshop will assist NASA in general, and the research divisions in OAST in particular in establishing a plan for the systematic development of space technology as an augmentation of the "Outlook for Space" study results. The technology group chairmen made a special effort to assure that their reports contained a National or NASA flavor rather than to necessarily represent traditional OAST roles.

The Logic Flow Chart illustrates the approach and procedures for meeting Workshop objectives.

"Technology needs" are the potential requirements and challenges identified with future NASA space missions which were used as the basis for "mission driven" technology planning.

"Technology opportunities" concern the identification of potential technology advances offering opportunities for new mission capabilities, performance improvement, or economy, to establish the basis for that portion of the technology planning which is "opportunity driven" and essentially decoupled from mission needs.

III. Organization and Staffing

The organization/staffing structure chart illustrates the breadth of included technology disciplines and Agency participation. Participants are listed in Appendix A.

A. Steering Committee

The Steering Committee was composed of senior OAST and OSF personnel whose responsibilities included recommending technology group chairmen, guiding the thrust and focus of Workshop activities and providing overall leadership.

B. Center Coordinators

The Center Coordinators were the points of contact for their respective centers for Workshop activities. Their intracenter liaison efforts were responsible for the selection and commitment of center personnel to participate in the Workshop.

C. Technology Panels

The eleven technology panels were composed of NASA Center and Headquarters personnel who were technical experts in their respective fields. These groups reviewed all source data and identified and documented research and technology program candidates which supported Workshop objectives.

The major product of the Workshop is the documented outputs from these technology panels. The chairmen requested members of the Steering Committee, Technology User Panels and Program Support Panel to participate in their respective technology panel activities, when and as required, to assure an end product that would effectively meet Workshop objectives.

D. Technology User Panel

The Technology User Panel represented the NASA program offices which are "users" of OAST-developed technology. This panel included members from OA, OSS, OSF, OTDA and selected center personnel.

Their tasks included providing a compilation of the planned technology needs and priorities for NASA programs projected for the 1980-2000 time period. This panel was on hand during the course of the Workshop to interpret and prioritize the various proposed program requirements, provide counsel to the technology panels and review the final recommendations of the technology panels for response to "users" needs.

E. Program Support Panel

The Program Support Panel included personnel from OSF and OAST and selected centers and was responsible for a variety of tasks. A key function was to provide background information on the capabilities, limitations and resources of the STS elements (shuttle, Spacelab and upper stages) and the results of studies related to the use of these elements. In addition to oral presentations of STS data at the beginning of the Workshop, consultants were available throughout the Workshop to provide information and guidance regarding use of the STS elements, including OAST's Advanced Technology Laboratory (ATL) and Long Duration Exposure Facility (LDEF) concepts.

This panel was also responsible for overall Workshop organization, management and support which included administration of a grant (NSG-1186) to Old Dominion University (ODU) for programmatic and logistic support.

D. Old Dominion University

The responsibilities of personnel from ODU's Mechanical Engineering and Mechanics Department included preparation of input data packages in consultation with technology panel chairmen; assembly, editing and publishing of final reports; providing or making arrangments for all on-site accommodations.

IV. Documentation

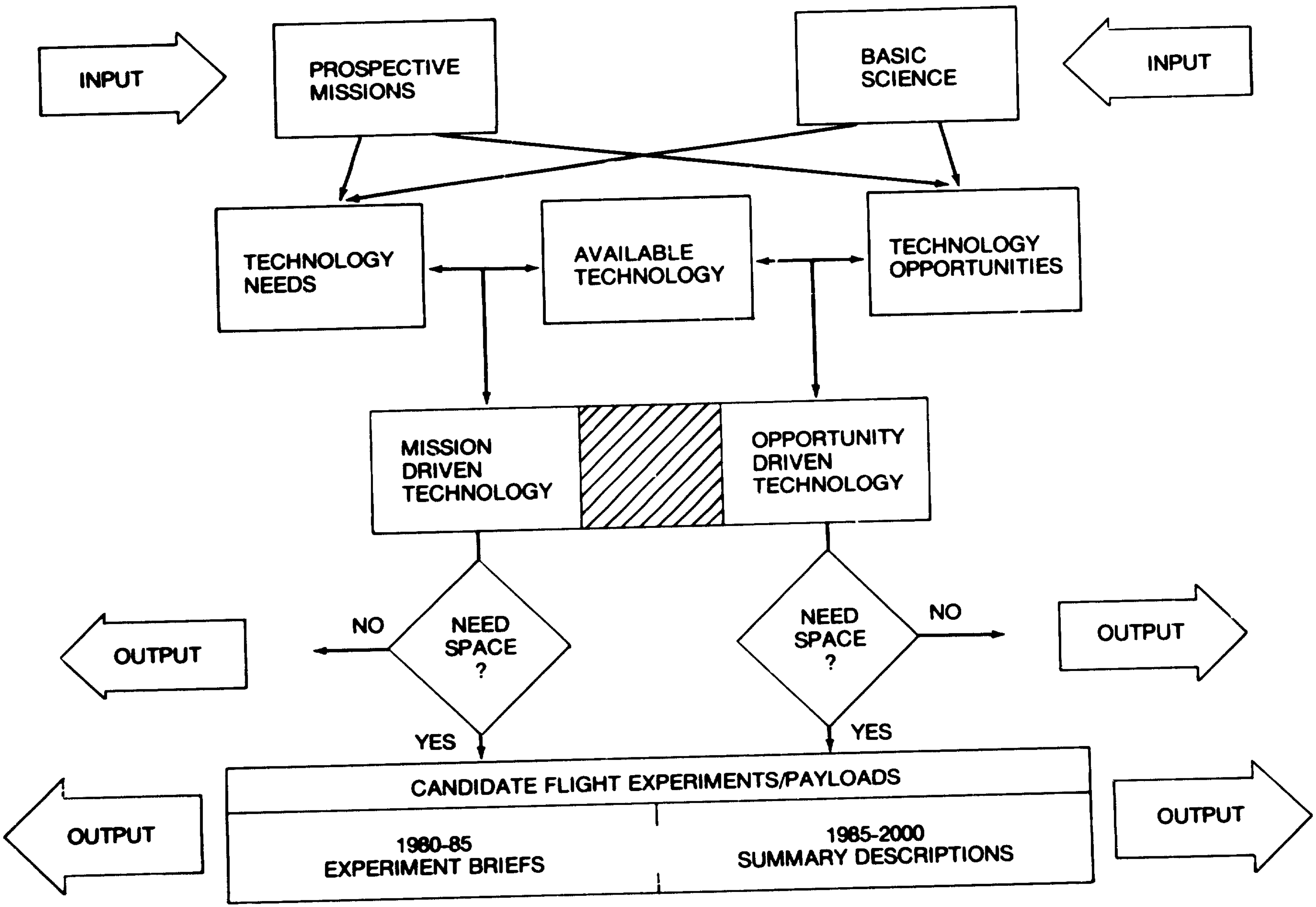
ODU personnel, in consultation with the technology panel chairmen, prepared an individual input data package for each technology panel using a "library" of about 175 source documents. This total "library" of source documents was available at the meeting site for participants' use. Technology panels were provided with copies of their individual discipline data package and the source documents listed in Appendix B.

The July 1975 "Outlook for Space" (OFS) Internal NASA Review Draft Report has been used as a reference document by authors of the Workshop reports. The OFS draft report has been revised and published as NASA SP-386, January 1976. The revisions should not affect traceability to OFS data referenced in Workshop reports. For example, although SP-386 contains some minor changes in the titles of the 12 themes, 61 objectives, and 240 systems, the numerical identification system is unchanged.

V. Oral Presentations

The first two days of the Workshop were devoted to oral presentations to amplify the Outlook for Space, technology "users" and OAST technology planning study inputs and to provide technical data on elements of the STS. The complete speakers' agenda is presented in Appendix C.

TECHNOLOGY WORKSHOP LOGIC



ORGANIZATIONAL/STAFFING STRUCTURE

PANEL \ ORGANIZATION	HQ	ARC	GSFC	FRC	JPL	JSC	KSC	LaRC	LeRC	MSFC	
STEERING	12										
DATA PROCESSING AND TRANSFER	3	1	1		1	2	1	1	1	1	
SENSING AND DATA ACQUISITION	2		1		1	1		4		1	
NAV., GUIDANCE AND CONTROL	1	1	1		3			1		1	
POWER	1		1		1	1		1	4	1	
PROPULSION	2		1		4				3	1	
STRUCTURES AND DYNAMICS	1		1		1			3	1	1	
MATERIALS	1	1	1		1			1	3	1	
THERMAL CONTROL	1	1	1		2			1	2	1	
ENTRY TECHNOLOGY	2	1			1			2			
BASIC RESEARCH	1	1			1			1	1	1	
LIFE SUPPORT	1	1				1				1	
TECHNOLOGY USERS	5		2		1			1		2	
PROGRAM SUPPORT	3							5			

Background

Establishing what the elements of an advanced technology program should be, and the time frame in which to develop them is a difficult task. Very long lead times are usually required; i.e., entry technology work initiated in the late 1950's at our Langley Research Center, laid the groundwork for the Shuttle—a time span of about two decades from initiation of technology to initial operation. Therefore, the way we go about planning our advanced space technology program is vitally important. OAST's job of structuring or selecting "the right" technologies, and their timing, must be maximized. We need the advice and assistance of the best this country has to offer; NASA's "Outlook for Space" (OFS) and the congressional subcommittee's hearings, "Future Space Programs 1975" have become major inputs to this process. One of the more recent technology requirements exercises that could be used as a point of departure for the subject technology workshop was the technology forecast portion of the overall NASA Outlook for Space study. As indicated in the following excerpts from the OFS Executive Summary, our charter for the workshop was more or less "drawn up".

In order that various candidate objectives could be assessed as to their technical feasibility, a Forecast of Space Technology was prepared and has been published as a separate report. The OFS forecast determined that between now and the year 2000 a great number of advances will occur in technology applicable to space activities. These developments will make feasible quite complex missions and systems and can significantly reduce the cost of accomplishing any specific objective in space.

Six predicted technological advances, described more completely in the OFS are summarized below. Each affects a broad spectrum of candidate objectives and represents an important example from the various fields of technology that were studied.

Before the year 2000, ultra-high density solid-state mass memory systems will be available, capable of storing 10^{12} bits per cubic meter, an increase of 10^4 beyond 1975 capabilities.

Major advances in automatic data processing, including data compression, information extraction and pattern recognition are needed.

Nuclear devices, particularly fission reactors with various electrical energy converters, if developed for space applications, offer the best promice for low-weight, low-cost energy storage of the energy storage systems deemed feasible between now and the year 2000.

Before the year 2000 it will be possible to design, fabricate, deploy and control large, light-weight structures in space such as solar arrays of the order of a square kilometer. For antennas, where pointing accuracies are more demanding, areas could be tens of thousands of square meters.

It could be possible by the year 2000 to provide nearly fully closed (fully recycling) biological life support systems for large crews in space or on the moon, with reliable lifetimes of several years and with "farm" areas of the order of 10^3 square meters per capita.

It could be possible in the time period in question to develop reusable, vertical landing (perhaps in water), heavy-lift vehicles for low-cost Earth-to-orbit transportation, capable of delivering payloads of a few hundred thousand kilograms to low-Earth orbit at a cost of [illegible] per kilogram.

The above examples span a large spectrum but provided a good background to bracket the scope of the OAST Technology Workshop. Those early in the listing represent technological advances which it would appear will take place with little if any pressure from the space program, but rather with the support of industry which in some cases will be funded by other federal agencies. Those near the latter end are examples of technology which are required almost solely for spaceflight activities. Some of the areas identified by the OFS report as Potential future projects requiring new technology.

1. Representative Requirements for Major Technological Advances

SPACE RADIO AND OPTICAL ASTRONOMY OBJECTIVES

- Structural integrity, stability, pointing requirements of very large telescope
- Cryogenic detector cooling in space
- Structures many 10's of meters with 0.01 second rms stability
- Large-scale antenna element arraying

DEEP SPACE OBJECTIVES

- In-situ organic analysis and back contamination control
- Autonomous spacecraft and vehicles
- Survivable landers for extreme and variant environments
- Increased navigation precision through multilateration and Quasi-VLBI technique
- Nuclear and solar electric propulsion to replace prohibitive costs of chemical rockets

SPACE PHENOMENA OBJECTIVES

- High-precision relativistic measurements, 10^{-17} clocks, 0.01 second/year gyroscopes
- Cryogenics in space
- Weather and climate modeling

EARTH ORBIT - EARTH INTERACTION OBJECTIVES

- Kilometers large, lightweight, low-cost structures
- Pointing accuracy with surface control to millimeters
- Assembly in space
- Low-cost energy converters

LIVING AND WORKING IN SPACE OBJECTIVES

- Bone resorption, cardiovascular, and other physiological and psychological effects
- Closed ecological and life support systems

2. Areas of Preparedness Technology:

- Very Large Scale and Lower Cost

  Space Transportation
  Controllable Lightweight Structures
  Space Energy Converters

End-to-End Information Management
Antenna Aperture and Arraying

- Very Long Life Components and Systems
- Large-Scale, Reliable Microcomponent Utilization
- Autonomous Spacecraft and Vehicles
- Precision Navigation
- Instruments and Sensors
- Nuclear Space Power and Propulsion Systems
- Advanced Propulsion
- Close Ecological and Life Support Systems
- Long Flight Physio-Psycho-Socio Implications
- Lunar Resource Recovery, Processing, and Space Manufacturing
- Planetary Environment Remedial Processes

3. Space Transportation:

Many missions which seem attractive over the next two decades can utilize either available launch vehicles or the Shuttle Transportation System. There are some, however, whose economic viability might well depend upon the development of a larger and more efficient launching system, of a type often referred to as the heavy-lift, low-cost launch vehicle. An example of a mission that would benefit from such a new launch vehicle is the Satellite Solar Power Station.

An examination of various conceptual designs for such large boosters indicated that it would be technically feasible, within the next two decades, to produce systems which could launch payloads into low Earth orbit with recurring costs of $50 per kg or less.

There are other propulsion developments which should be considered in this same time frame, particularly those concerned with high energy missions such as the exploration of the planets. There has already been a considerable amount of development work on electric propulsion techniques using either solar energy or nuclear energy as a power source. These developments are highly promising. It would seem that such techniques offer the most cost effective manner for accomplishing some of the important deep space missions (for example, comet rendezvous).

4. Beyond the year 2000:

Some of the conclusions reached by the OFS Study Group were based on an assessment of space possibilities in the more distant future; that is, beyond the turn of the century. A detailed examination of these future possibilities was not within the scope of the study, yet they were considered since the foundations for their achievement will be laid down within the next 25 years.

Many post-2000 activities will result from the natural evolution of space capabilities. We will steadily improve our ability to monitor the surface and the atmosphere of the Earth, and better understand the increased data which improved systems will make available to us. We will have much greater capability to explore our solar system and observe the rest of space, and a much deeper understanding of the nature of the Universe to guide our explorations.

There are other activities which are not so directly a result of evolutionary growth. It is not possible to predict when such future activities might occur, but we believe those programs near the top of the following list are likely to be undertaken before those near the bottom:

Occupation of the Moon.
Commercial space transportation of people and goods.
Returning refined lunar minerals.
Industry in space.
Habitats in space.
Human exploration of Mars, other planets and their moons.
Mining the asteroids.
Making other planets or moons habitable.
Interstellar flight.

From the above OFS stimuli and other "user" inputs, the Workshop was launched and ultimately generated some 200 flight experiments that need OAST attention as well as many other excellent R&T base technology requirements.

Some of the major thrusts and goals emerging from the OAST Workshop involved major OAST technology disciplines of space electronics, propulsion and structures. Examples of some of these thrusts and goals are as follows:

Structures

1. Develop and verify erectable structures technology for large (1 km) space structures by 1985. (Goal)

2. Develop composites technology to provide a weight savings of 30% to 50% in LASS. (Goal)

3. Experiments to verify erection techniques for large structures in orbit. (Goal)

Propulsion

1. Reduce space transportation cost (thrust)

Earth to Leo	500 \$/kg - 50\$/kg
Earth to GSO or escape	3000 \$/kg - 500 \$/kg
Earth to outer solar system	5×10^6 \$/kg - 3000 \$/kg

Electronics - Data Handling, Sensing and G.N.C. Data Handling·

1. 1000:1 Information Capacity Increase (thrust)
   - Increased data load
     - Applications Growth
     - Sensor Output Growth
     - Mission Model Growth
   - Data System Saturation
     - Inadequate data transfer links
     - Data analysis delay and cost
     - Data Warehousing and Retrieval costs

2. 10:1 Life-Cycle Cost Reduction (thrust)
   - Research and Development Costs
     - Large numbers of payloads
     - Variable requirements
       - System architecture
       - Software
     - System Acquisition Costs
     - Operation Costs
       - Reliability
       - Support
       - Software
         - Modification
         - Maintenance

3. Technology Requirements - Goal #1
   - High Capacity Links
     - Wideband Microwave
     - Gigabit Earth-Vicinity
       - Millimeter Waves
       - Laser
     - Medium Bandwidth Planetary
       - Microwave
       - Laser
   - Information Extraction
     - Data vs. information
     - Feature identification
     - Payload Peculiar

4. Technology Requirements - Goal #2
   - Modular Architecture
     - Family of configurations
     - User-needs Adaptable
     - Growth capability
     - Standard Components
   - Fault-Tolerant Systems
     - Built-in test
     - Diagnostics and Corrective Action
     - Memory Purging
     - Software Error Protection
   - Automated Fault-Tolerant Software Generation
     - Structured
     - Automatically generated
     - Automatically verified

5. <u>Sensing</u>
Provide a 10-fold increase in mission output through improved sensing accuracy, resolution and spectral range by 1985 (thrust).

6. Reduce information system cost by 1 to 2 orders of magnitude through extensive integration of sensor and onboard processing technology by 1985 (thrust).

7. Provide the capability for near real time, low cost, global surveys through multipurpose, all weather active/passive microwave systems by 1990. (thrust)

<u>Guidance, Navigation and Control</u>

8. Reduce Mission support costs by 50% through autonomous operations by 1990.

9. Provide a ten-fold increase in mission output through improved pointing and control by 1990.

10. Provide a hundred-fold increase in human's productivity in space through large scale teleoperator application by 1990.

In summary, the Workshop accomplished two major objectives for OAST: (1) we formulated technology needs which addressed recommendations from our users, early drafts of the "Outlook for Space", and other sources; and (2) we defined Shuttle flight experiments and payloads which would enhance bringing those technologies to a satisfactory state of readiness.

SYNOPSIS

DATA PROCESSING AND TRANSFER

VOLUME I of XI

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INTRODUCTION

This document contains a brief description of the final report of the Data Processing and Transfer Technology Panel. The prime objective of the group was to identify the Data Processing and Transfer Technology areas that need to be developed for future activities in space. The technology areas are subdivided into two categories: Mission Driven and Opportunity Driven. Also included in the final report are technology areas which demonstrate feasibility and economic viability of quite complex missions and systems and significantly reduce the cost of accomplishing many specific objectives in space.

The list of experiment titles following the summary is an index to the sections describing the technology areas identified by the working group. Each section describes the objectives of the technology area identified, scope, approach and projected impact on future space activities.

SUMMARY

In order to define the requirements, technology needs and flight experiments in the Data Processing and Transfer Technology, the working group considered all of the inputs provided by the user community. These inputs, as well as applicable items from Outlook for Space, were used as primary inputs by the working group. The input material ranged from the basic areas of communications, earth observations, earth and ocean physics and astronomy, to specific needs in planetary communications, image enhancement narrowband TV, reduced BW for real time TV and deep-space data systems. All of these inputs combined to form an ensemble which covers a rather wide spectrum of data related technologies. A tabulation of the user community inputs is contained in Section II of the technology group report.

The scope of the various inputs led to the formulation of two major program thrusts:

1. 1000:1 increase in end-to-end information handling
2. Life cycle cost reduction of 10:1

In the deliberations, several additional areas of technology were identified which were too broad for inclusion in one of the major thrusts; and to avoid loss of identity, these topics have been grouped under the heading of supporting technology. The working group also identified the extensive technology development in progress. These efforts and the technological advances advocated by this technology working group affect a broad spectrum of candidate objectives for future space activities. These developments will not only demonstrate feasibility and economic viability of quite complex missions and systems but also significantly reduce the cost of accomplishing many specific objectives in space.

The technologies and flight experiments in need of development fall into the groups below:

1. High Data Rate Processing
2. Information Extraction & Data Compression
3. Wideband Information Transfer
4. High Density, Low Cost Storage
5. Modular Architecture
6. Manned Ineraction
7. Communications

8. Software
9. Electronic and Modular Structure
10. End-to-End Information Handling
11. General Supporting Technology

The specific technology requirements and flight experiments are shown in Tables 1.1 and 1.2.

TABLE 1.1

DATA PROCESSING AND TRANSFER

1.	Recognition Processing of Image Type Data On-Board Spacecraft	M
2.	On-Board Processing of Multispectral Scanner Data	M
3.	Modular Parallel Pipe-Line Processor (MPPP)	M
4.	Information Extraction & Data Compression	M
5.	Laser Data Transfer	M
6.	Millimeter Waves for Spacecraft/Spacecraft Data Transfer	M
7.	High Capacity Ku-Band Communication Terminal	M
8.	Low Cost Reliable Modular Microwave Communications Active Antenna	M
9.	Light Weight Transponder	M
10.	On-Board Solid State Data Storage Systems	M
11.	Low Cost Random Access Memory	M
12.	Bulk Data Storage For Spacecraft (10^{12} and larger)	M
13.	Mass Memory for Processing Acquired Data	M
14.	Modular Architecture for Data Processing & Transfer Systems	M
15.	Vision Enhancement & Assistance for Teleoperator Control Systems	O
16.	Direct Broadcast/Narrowcast Systems	O
17.	Satellite Data Collection	O
18.	Trunking & Telephony Systems	O
19.	Spectrum Monitoring Technology (RFI)	O
20.	Coordination of NASA R&D In Computer & Information Science	M
21.	Software Generation & Human-Machine Interaction	M
22.	Software Management	M
23.	Automation of Group Support Functions	M
24.	Networking for NASA Computer Facility & Software Sharing	M
25.	Information Extraction & Data Compression	M
26.	Standard Electronic Modules for Space Payloads & Group Support	M
27.	Fault Tolerant Electronic Systems	M
28.	System Engineering Techniques Using Modeling & Simulation	M
29.	Transfer of Space Power by Microwaves	M
30.	Radiation Tolerant Electronic Components & Subsystems	M

(M - Mission Driven)
(O - Opportunity Driven)

TABLE 1.2

DATA PROCESSING & TRANSFER
FLIGHT EXPERIMENTS

1.	End-to-End Integrated Data System	M
2.	High Capacity Ku Band Communication Terminal	M
3.	Laser Data Relay Link	M
4.	Communication Technology Experiments	O
5.	Preprocessor For Multifrequency Synthetic Aperture	M
6.	On-Board Manned Interactive Multisensor Image Processor	M
7.	Advanced Teleoperator Vision System	M
8.	Modular Architecture for Data Processing & Transfer System	M
9.	Automation of Group Support Functions	M
10.	Radiation Tolerant Electronic Components & Subsystems	M
11.	Transfer of Space Power by Microwaves	M

(M - Mission Driven)
(O - Opportunity Driven)

SYNOPSIS

SENSING AND DATA ACQUISITION

VOLUME II of XI

INTRODUCTION

This document contains a brief description of the final report of the Sensing and Data Acquisition Panel. The objective of the panel was to identify the Sensing and Data Acquisition technology areas that need to be developed for future activities in space.

The total final report is contained in one volume but is separated into two parts, Report I and Report II. Report I covers the synthesis of payloads and associated advanced technology requirements defined by the group. Report II covers those advanced technology requirements that did not have a sensible development approach as part of a payload in Report II.

In defining payloads within the context of "user" inputs and the Outlook for Space themes, it became apparent that multiple concepts of payloads were needed. Some members of the working panel saw payloads as a component level evaluation. Others saw payloads as a system level requirement, allowing the various components to interact. Still others saw payloads as an advanced system, functionally interacting with the real environment and performing useful measurements. The working panel endorsed all three concepts of payloads and in doing so recognized that NASA payloads were being defined, requiring a close partnership between OAST and the "user" program offices.

The working panel output is by no means an exhaustive treatment of the sensing and data acquisition descipline. Further expansion of the payloads is also possible. However, the payloads selected are considered to represent an effective blend of advanced technology thrusts, most having multi-user impact.

SUMMARY

The Sensing and Data Acquisition Working Panel followed the basic guidelines proposed by OAST for identifying the mission and opportunity driven technology requirements and candidate space experiments. The major thrusts set out by the group were as follows: (1) provide a 10-fold increase in mission output through improved sensing accuracy, resolution and spectral range by 1985; (2) reduce information system cost by 1 to 2 orders of magnitude through extensive integration of sensor and on-board processing technology by 1985; and, (3) provide the capability for near real time, low cost, global surveys through multi-purpose, all weather active/passive microwave systems by 1990. The relevance of these thrusts was demonstrated by identifying various payload experiments and through several examples of payload/major thrusts relationships. The payloads were the primary product of the workshop and were responsive to "user" inputs as well as possible national space themes contained in the recently completed NASA study, Outlook for Space. Table 1 is a listing of the 16 Sensing and Data Acquisition payloads that were identified and are addressed in Report I. Table 2 lists the advanced technology areas addressed in Report II. It is suggested that the workshop results should be considered as the beginning of a process to relate advanced technology to potential shuttle payloads.

Table 1 - SENSING AND DATA ACQUISITION PAYLOADS

ATMOSPHERIC SENSING PAYLOADS

- Stratospheric Trace Gas Effects
- Global Aerosols and Gases
- Laser Remote Sensing of the Atmosphere
- Earth Energy Budget and Solar Irradiance Measurements
- Multiwavelength Atmospheric Transmission

EARTH RESOURCES SENSING PAYLOADS

- Coastal Zone and Land Resource Management

MICROWAVE SYSTEMS SENSING PAYLOADS

- Advanced Microwave Radiometer Systems
- Advanced Radar/Scatterometer Systems
- Advanced Meteorological Radar

TECHNOLOGY DEVELOPMENT/EVALUATION PAYLOADS

- Large Deployable Microwave Antennas
- Radar Calibration System
- Submillimeter Wavelength Receivers
- Earth Viewing IR Component Evaluation

ASTRONOMY/PLANETARY PAYLOADS

- Extreme Ultraviolet Astronomy
- Infrared Astronomy/Column Density Monitor
- Infrared Astronomy/Advanced Technology Radiometer

Table 2 - REPORT II TECHNOLOGY AREAS

A. Remote Sensing Systems
   1. Microwave and Radar
   2. Lasers
   3. Imaging Systems
   4. Radiometers and IR Instruments
   5. X- and Gamma-Ray Instruments

B. Fields and Particles
   1. Electric Fields
   2. Magnetic Fields
   3. Charged Particles

C. In-Situ Properties
   1. Geochemical
   2. Geophysical
   3. Atmospheric

D. Supporting Research and Technology

SYNOPSIS

NAVIGATION, GUIDANCE AND CONTROL

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INTRODUCTION

This document contains a brief description of the final report of the Navigation, Guidance and Control (NGC) Panel.

The objectives of the panel were to (1) identify technology requirements based on existing or anticipated user needs, and (2) identify NGC shuttle experiments complementing these requirements. The experiments identified were documented and categorized as to whether they were mission driven or opportunity driven. Further, these experiments were justified as to their need of the space environment, their cost effectiveness when performed on the shuttle, or their requirement for user acceptance.

Following this section, a summary of the NGC final report is presented which explains panel procedures, NGC major thrusts, and presents rationale for the identified experiments and experiment groupings. Finally, Table I lists the NGC technology requirements and Table II lists shuttle payload experiments and experiment groupings; Table III lists experiment categorization and justification.

SUMMARY

The Navigation, Guidance and Control (NGC) Panel collected "user" technology requirements found in the "Outlook for Space" Document, and inputs from user groups such as OSS, OA and OMSF. These user requirements were compared with technology requirements generated prior to the Workshop. New technology requirements were subsequently developed and revisions and modifications of existing technology requirements were made in light of user needs.

The user requirements were then grouped into three major thrusts. These major thrusts provide a blanket for related technology advancement or improvement and support several of the NASA user offices. These major thrusts are:

1. Reduce mission support cost by 50% through autonomous operation by 1990;
2. Provide a ten-fold increase in mission output through improved pointing and control by 1990; and,
3. Provide a hundred-fold increase in human's productivity in space through large-scale teleoperator applications by 1990.

In all, 47 technology requirements were identified that support user requirements. General emphases could be identified under each of the three major thrusts. These emphases are:

Autonomous Operations

- Long Life Components and Systems
- Autonomous Spacecraft and Systems
- Self-Repairing Spacecraft Systems
- Automated G&C Electronics
- Long Life Time Reliability Assurance

Pointing and Control

- Large Arrays and Structures
- Interplanetary Instrument Pointing
- Earth Orbital Pointing and Attitude Control
- **Precision Instrument Pointing for Manned Missions**

Teleoperators

In-Space Construction Techniques
Orbital Assembly, Maintenance, Repair
Remote Controlled Manipulators

All of the technology requirements are listed in Table 1.

Next, the technology requirements were reviewed to determine if they could benefit from a shuttle flight experiment. A total of 15 were identified that could benefit from a flight test. Some of the future payload technology space tests require or are enhanced by the space environment, while others benefit from a systems test, required for user acceptance, that can only be performed meaningfully in space. In some cases, it appeared that one shuttle flight might be able to accommodate several experiments in a single flight experiment package. Two of these packages were identified as:

1. Inertial Components Test Facility including low g accelerometer experiments and redundant strapdown Inertial Measurement Unit experiments; and,
2. Modular Instrument Pointing Test Facility including experiments related to optical and video correlator landmark trackers and the Video Inertial Pointing System for shuttle astronomy payloads.

The complete set of shuttle payload experiments and experiment groupings are presented in Table 2. Table 3 shows each proposed experiment, its basis for justification and whether it is opportunity-driven or mission-driven.

Table I NGC Technology Requirements

I. Autonomous Operation of Spacecraft

1. Low Cost Navigation Independent of NASA Tracking Facilities
2. Approach Guidance from a Spinning Spacecraft
3. Scanning Laser Radar
4. Development of Low Cost Navigation Components
5. Autonomous Guidance and Navigation
6. Differential Very Long Baseline Interferometry (ΔVBI) and Pulsar Navigation
7. Comet and Asteroid Ephemerides Improvement
8. Cometary Intercept Navigation and Guidance
9. Automated Spacecraft
10. Robotic Decision Making and Planning
11. Robotic Scene Analysis
12. End Effector Sensors for Robot and Teleoperator Manipulators
13. Unassigned

II. Pointing and Control

A. Sensors

14. Stellar II (Star Tracker)
*15. Intensified Solid State Imaging Device
*16. Charge Injection Device for Low Light Level Imaging
17. Optical Standardization and Improved Tube Design for Star Trackers
18. Stray-Light Rejection
19. High Resolution Long Life Inertial Reference Unit
*20. Cryogenic Gyroscopes for Space and Aircraft Navigation
21. Continued Development of Digital Rebalance Electronics for Dry Tuned Rotor Gyros
22. High Resolution Attitude Sensor
23. Low g Accelerometer Evaluation Facility
24. Rate Gyro Package
25. Redundant Strapdown Laser Inertial Measurement Unit (IMU) For Space Missions
26. Optical Correlator Landmark Tracker
27. Video Correlator Landmark Tracker
*28. Optical Inertial Reference
29. Unassigned.

B. Systems and Components

30. Hard Lander Control System for Airless Planets
31. Video Inertial Pointing System for Shuttle Astronomy Payload
32. Attitude Control of Flexible Spacecraft Configurations
33. Figure Control of Large Deformable Structures
34. High Accuracy Instrument Pointing System for Flexible Body Spacecraft
35. Spacecraft Surface Force Control (SURFCON) and Attitude Control System
36. Radiation Attitude Control for Extended Life Planetary Missions
*37. Fluid Momentum Generator
38. Measurement and Control of Long Baseline Structures
39. Magnetic Large Array Assembly and Shape Management
40. Unassigned

III. Teleoperators

41. Space Teleoperator Technology
42. Supervisory Control of Remote Manipulators
43. Satellite Servicing
44. Multi Purpose Panel
45. End Effectors and Sensors
46. Teleoperator Controllers
47. Wrist Mechanisms
48. Miniature TV Camera
49. Image Enhancement
50. Video Signal Communications

* Referred to other working groups

Table 2 Shuttle Payload Experiments and Experiment Groupings

Major Thrust — REDUCE MISSION SUPPORT COST BY 50% THROUGH AUTONOMOUS OPERATION BY 1990

Experiments:
1. Low Cost Navigation Independent of NASA Tracking Facilities
2. Scanning Laser Radar (SLR)

Major Thrust — PROVIDE A TEN-FOLD INCREASE IN MISSION OUTPUT THROUGH IMPROVED POINTING AND CONTROL BY 1990

Experiment Groupings:

Title: 1. Modular Instrument Pointing Technology Laboratory (MIPTL) Individual Experiments:
a. Optical Correlator Landmark Tracker
b. Video Correlator Landmark Tracker
c. Video Inertial Pointing System for Shuttle Astronomy Payloads

Title: 2. Inertial Components Flight Test Facility Individual Experiments:
a. Low Gravity Accelerometer Testing
b. Redundant Strapdown Laser Inertial Measurement Unit for Space Missions

Other Experiments:

3. Stray Light Rejection Testing

4. Attitude Control of a Flexible Structure

5. Figure Control of Large Deformable Structures

6. Free Flying Interferometer

Major Thrust — PROVIDE A HUNDRED-FOLD INCREASE IN HUMANS PRODUCTIVITY IN SPACE THROUGH LARGE-SCALE TELEOPERATOR APPLICATION BY 1990

Experiments:
1. Teleoperator Orbiter Bay Experiments (TOBE)
2. Earth Orbital Teleoperator System (EOTS)

Table 3 Experiment Justification and Categorization

SHUTTLE EXPERIMENTS	OD/MD+	JUSTIFICATION: NEED SPACE ENVIRONMENT	JUSTIFICATION: SHUTTLE COST EFFECTIVE	JUSTIFICATION: REQUIRED FOR USER ACCEPTANCE
Low Cost Navigation	OD	X	X	
Scanning Laser Radar	MD		X	X
Stray Light Rejection	MD		X	
Low G Accelerometers	MD	X	X	
Redundant Strapdown IMU	MD			X
Optical Correlator Landmark Tracker	MD		X	X
Video Correlator Landmark Tracker	MD		X	X
Video Inertial Pointer	MD		X	X
Attitude Control of Flexible Spacecraft	MD	X	X	
Figure Control of Large Structures	MD	X	X	
Teleoperator Orbital Bay Experiment	MD	X		X
Earth Orbital Teleoperator System	MD	X		X
Modular Instrument Pointing Technology Laboratory (MIPTL)	MD	X	X	
Inertial Components Flight Test Facility	MD	X		X
Free Flying Interferometer Elements	MD	X		X

(MD=Mission Driven, OD=Opportunity Driven)

SYNOPSIS

POWER

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INTRODUCTION

This document contains a brief description of the final report of the Power Working Group (PWG).

The objective of the Workshop as understood by the PWG was to identify, for the consideration of OAST management, three specific areas of space technology for possible pursuit. The technology areas are listed below, with special emphasis to be placed on Item 1.

1. Shuttle Payloads--technology experiments which might make use of the capabilities of the Space Transport System.

2. Mission Driven Technology--technology needed to accomplish the missions in the '73 Mission Model, or technology which if suitably developed would offer significant improvements over the level of technology currently in use.

3. Opportunity Driven Technology--technology needed to support potential space opportunities of the future as identified by users.

The technologies listed are compilations of inputs from various sources. They are not a recommended listing nor is any priority to be inferred. Further, they are probably not a comprehensive list. The three technology areas listed above are treated separately in Volumes I, II and III.

The approach taken by the PWG took the following chronology:

Assemblage of input materials and data
Subdivision of power systems into subsystems and assignments of members to each subsystem
Generation of technology areas by subsystems
Review of technology areas by entire PWG
Drawing of conclusions
Preparation of presentation to management and final report

SUMMARY

Within the guidelines proposed by OAST, the Power Working Group (PWG) established the objectives of identifying the technology requirements for three basic areas of space technology: Shuttle Payloads, Mission Driven Technology and Opportunity Driven Technology. Each of these three areas was further subdivided and considered according to the following outline of Space Power System Elements:
(I) Energy Sources and Conversion (A. Solar Photovoltaics, B. Solar and Nuclear Thermal Electric, C. Chemical Conversion, D. Ambient Field Trapping); (II) Power Processing, Distribution, Conversion and Transmission; and (III) Storage. Tables I and II contain a more detailed breakdown of this outline and Figure 1 presents a pictorial of this subdivision of Space Power System Elements. Various technology areas have been suggested for OAST consideration. These are compilation of inputs from various sources and have been discussed in detail in the report. The main conclusions reached by the PWG are as follows: (1) power system technology currently available is adequate to accomplish all missions in the 1973 Mission Model; (2) Im-

proved Power Systems technology can provide significant benefits in operational capabilities and costs, even for the 1973 Mission Model (sixteen such areas have been identified); (3) Major advancements in Power Systems technology must be made if the Outlook for Space and other advanced user plans are to be accomplished; (4) A vigorous space experiment program is needed to achieve these accomplishments. Specifically, 23 space experiments have been identified.

Table III lists the 23 Shuttle Payloads which are addressed in Volume I of the final report. Table IV lists the 16 Mission Driven Technology Requirements which are addressed in Volume II of the final report. Table V lists the 19 Opportunity Drivers which are addressed in Volume III of the final report.

Table I Detailed Outline of Space Power System Elements

I. Energy Sources and Convertors

A. Solar Photovoltaic

1. HVSA
2. Solar Concentrators
3. Plasma Interactions with HV Surfaces
4. Large Scale Array
5. Array Deployment and Dynamics
6. Qualification of Cells
7. Achieving High Efficiency
8. Shuttle Calibration Facility
9. Tethered Array
10. Power Transfer
11. Advanced Concepts

A. EWECS

B. Solar and Nuclear Thermal Electric

1. Solar Concentrators
2. Brayton Cycle
3. Rankine Cycle
4. Stirling Cycle
5. Thermionic
6. Thermoelectric
7. Dielectric
8. MHD
9. RTGS
10. Reactors

C. Chemical Conversion

1. Dynamic Conversion
2. Primary Fuel Cells
3. Primary Batteries

D. Ambient Field Trapping

II. Power Processing, Distribution, Conversion and Transmission

A. Processing
B. Conversion
   Laser Photovoltaic
C. Distribution
D. Transmission
   1. Microwave
   2. Laser

III. Storage

A. Mechanical
B. Thermal
C. Chemical
   Regenerative Fuel Cells
D. Electrochemical

Table II DEVELOPMENT THRUSTS

	CURRENT	NEAR TERM	DEVLPMNT TARGETS	MISSION-DRIVEN
SOLAR-PV ARRAYS (WATTS/KG)	60	100-110	200	1100 (SSPS)
ENERGY STORAGE (WATT-HR/KG)	20-30	40-50	100	300
POWER SYSTEMS (KWE)	25	25		MULTI-MWE (Large Manned and Lunar Stations)

Table III Shuttle Payloads Included in Volume I

I. Energy Sources & Conversion

A. Solar Photovoltair

1. Deployment, Retraction and Dynamics of Lightweight Structures for Solar Cell Arrays
2. Demonstration of High Voltage Solar Cell Array and High Voltage Power Management for SEPS
3. SSPS Technology Testing and Demonstration Experiments
4. Measurement of Solar Radiation Intensity and Spectral Distribution
5. Environmental Tests of Advanced Solar Cells
6. Environmental Tests of Materials for Advanced Solar Cell Arrays
7. Liquid Metal Slip Ring Experiment
8. Extended Environmental Testing of Solar Array Mechanisms and Materials
9. In Space Assembly of High Power Transfer Devices
10. Environmental Tests of Advanced Solar Cell Modules and Subarrays

B. Solar and Nuclear Thermo Electric

1. Demonstrate Emergency Cooling System in Zero-Gravity for Brayton Isotope Power System
2. Demonstration of Brayton Isotope Power in Pointing Experiment for Large Concentrators
3. Scalable, Free Flying Facility for Testing of High Power Density Components
4. Demonstration of a 500 KWe Solar Brayton Space Power System for Transmitting Electric Power to Earth
5. Demonstration of a 100 KWe Nuclear Space Power System (Brayton-Thermionic) for Electric Power or Propulsion

C. Energy Conversion - Chemical

1. Radio Frequency Mass Quantity Gauging

II. Power Processing, Distribution, Conversion & Transmission

1. Unattended Utility Power Station
2. Sphinx B
3. Sphinx C
4. Flight Demonstration of Power System Components Cooled by Integral Heat Pipes
5. SEPS Prime Propulsion Demonstration

III. Storage

1. Silver-Zinc Cell Experiment
2. High Energy Density Battery Experiment

Table IV Mission Driven Technology Requirements Included in Volume II

I. Energy Sources and Conversion

A. Solar Photovoltaic

1. Solar Cell Array for Electric Propulsion
2. High Efficiency, Low Cost, Radiation Resistant, Light-Weight, Silicon Solar Cells
3. Power Transfer Across Rotating Joints
4. High Temperature, High Efficiency, Radiation Resistant III-V Compound Solar Cells

B. Solar and Thermo Electric

None

C. Chemical Conversion

1. Hydrogen/Oxygen Fuel Cell Module for Tug
2. Radio Frequency Mass Quantity Gauging

II. Power Processing, Distribution, Conversion and Transmission

1. Spacecraft Charging and High Voltage Interactions with Plasma
2. Unattended Utility Power Station
3. Automated Power Systems Management
4. Solar Array Power Generation and Management, HVSA
5. Advanced Power Processing/Monitoring System
6. Multi KW, High Voltage Power Processor and Distribution System for Special Applications
7. Self-Aligning Multipin Low/High Voltage Electrical Connector Assembly

III. Storage

1. Ni-Cd Secondary Battery System for LST
2. Ni-H_2 Energy Storage System for Low Earth Orbit, Long Life Payloads, LST
3. High Energy Density Batteries

Table V Opportunity Drivers Included in Volume III

I. Energy Sources and Conversion

A. Solar Photovoltaic

1. Solar cell array for SSPS
2. High Efficiency, Radiation Resistant, High Temperature, Light-weight Solar Cells
3. Multi-junction, Edge-Illuminated Silicon Solar Cell
4. High Efficiency, Low Cost, Radiation Resistant Electromagnetic Wave Energy Generator (EWEG)

B. Solar and Nuclear Thermo Electric

1. Solar Concentrators for High Temperature Energy Conversion to Electric Power

2. Nuclear Electric Power for Propulsion or Large Power Uses
3. Extra-Terrestrial Brayton Energy Conversion (Solar & Nuclear Heat Sources)
4. Extra-Terrestrial Stirling Energy Conversion (Solar & Nuclear Heat Sources)
5. High Performance Thermionic Conversion
6. Solar Dielectric Power Conversion
7. Nuclear Thermoelectric Power Systems

C. Chemical Conversion

1. Dielectric Film Stack Cryogenic Tank Insulation
2. Advanced Fuel Cell Technology

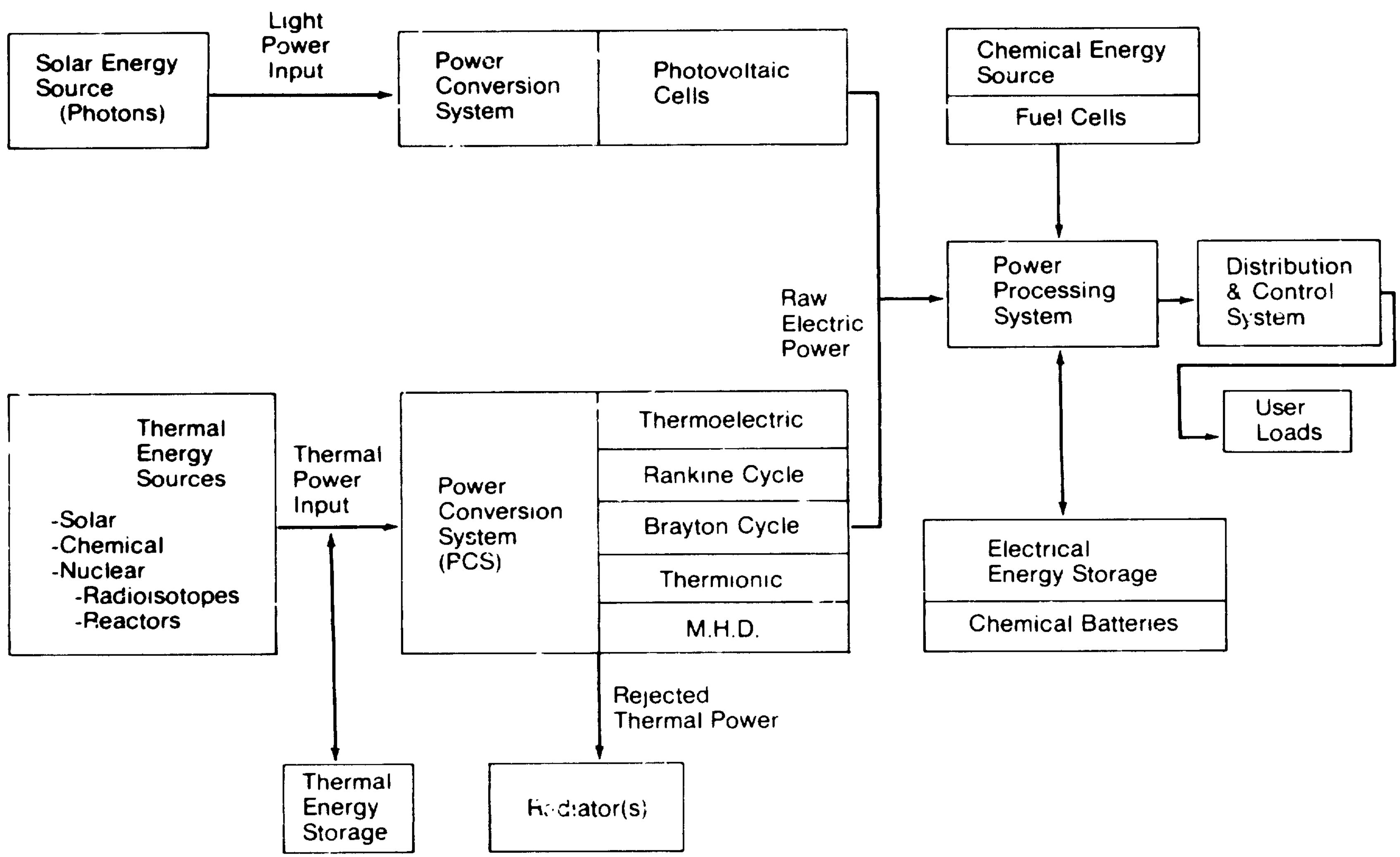
II. Power Processing, Distribution, Conversion and Transmission

1. Power Processing and Distribution Systems for Gigawatt Class Power Systems
2. Higher Bus Voltage Power Processor and Distribution System Technology
3. Laser Energy Photovoltaic Converter
4. Ultra High Power Energy Conversion and Transmission System Technology

III. Storage

1. Large Ni-Cd Batteries for Space Station Application
2. Use of Flywheels for Mechanical Storage of Energy

Fig. i: SPACE POWER SYSTEM ELEMENTS



SYNOPSIS

PROPULSION

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INTRODUCTION

The Propulsion Technology Working Panel Report has been divided into two parts. Part I has summarized the Panel's effort to identify and classify appropriate advanced technology requirements which are consistent with the needs described by the Technology User Group and of the Outlook for Space Study. Part II has summarized the experimental aspects of that technology which might be advantageously carried out in near-earth space using the Shuttle Orbiter, its payload bay, the Spacelab and/or some free flying device that might be used for long-duration testing.

The major goal for propulsion technology was to reduce space transport costs in order to facilitate all the goals of the space program.

The central point of the Panel's effort was the Table of Advanced Technology Requirements which summarizes the propulsion technologies considered during the Workshop, along with the technology driver (either a specific type of mission or a new technology opportunity). In addition, the Table has catagorized each technology according to its state of readiness as well as its relationship to the major thrusts identified by the Panel.

SUMMARY

Three major cost reduction thrusts were developed as directions for advanced propulsion technology development. They are:

1. Reduce cost of transport from earth to low earth orbit from 500 \$/kg to 50 \$/kg;
2. Reduce cost of transport from earth to geosynchronous orbit from \$3000/kg to 500 \$/kg.
3. Reduce cost of transport from earth to the outer reaches of the planet from 3×10^6 \$/kg to 3000 \$/kg.

The relative importance of each of the three thrusts depends to a large extent on the specific missions ultimately given priority by NASA. Consequently, the group has identified technology areas according to the type mission which would drive research in that area. The present state of development of the particular technology has been assessed and it has been identified with at least one of the three major thrusts. The accompanying Table of Advanced Technology Requirements represents a summary of the findings of the Propulsion Technology Working Group.

Code	Current Status	Readiness Date
A	In Use	Prior to 1975
B	Near Term	1975-1985
C	Far Term	1985-2000
D	Conceptual	Post 2000

Candidate payload experiments were also identified which could be advantageously carried out in near-earth space using the Shuttle Orbiter, its payload bay, the Spacelab and/or some free-flying device that might be used for long duration testing. The nineteen experiments identified were grouped in three categories according to the principal rationale for carrying out experiments in space:

I. The special characteristics of the space environment makes testing from the Shuttle Orbiter and its related equipment the only, or most reasonable, approach for obtaining data.

II. Testing in space is expected to be more cost-effective than carrying out similar tests on earth.

III. Tests in near-earth space provide a very close approximation to the conditions to be encountered by operating systems and as such may reveal unforseen problems of operations in space or may otherwise provide risk reduction for the hardware design. In this way, space testing will aid in giving user acceptance of a new technology. The accompanying Table of Advanced Technology Requirements summarizes the propulsion technologies considered by the Panel.

TABLE OF ADVANCED TECHNOLOGY REQUIREMENTS

I. Chemical Propulsion Technology	Technology (1) Driver	Technology (2) Readiness Code	Major (3) Thrusts Code
A. Stable			
(1) Liquid			
a. F_2/N_2H_4S/C Propulsion Subsystem	M4, 5	B	(b)
b. Long-Life Hydrazine	M1, 4, 5	A	(b)
c. Long-Life Earth Storable Propellant	M1, 4, 5	A	(b)
d. Adv. Launch Vehicle Engines using High-Density Fuel and Oxidizer	M2	C	(a)
e. Adv. Launch Vehicle Engines using H /O Propellants	M2	C	(a)
f. Densification of Cryogens by use of Slush or Triple Point Fluid	M2	B	(a), (b)
g. High Pc H_2/O_2 Upper Stage Engine	M2, 3, 4	B	(b)
h. Tank Head - Idle and Extendable Nozzle for Low-to Moderate Chamber Pressure H_2/O_2 Space Engine	M3, 4	B	(b)
i. Small H_2/O_2 Main And Auxiliary Propulsion Sy stems	M1, 4	C	(b), (c)
j. High Perf. High Density Space Engines (including dual fuel alternatives to H_2/O_2)	M2, 3, 5	C	(b)
k. Low Cost Liquid Booster Engines	M2	C	(a)

	Technology (1) Driver	Technology (2) Readiness Code	Major (3) Thrusts Code
l. High Performance Cryogenic Insulation for Reusable Spacecraft	M1, 3, 4, 5	A	(a), (b)
m. Insulation for Reusable H_2 Tanks for Advanced Boosters	M2	B	(a), (b)
n. High Temperature and High Strength to Weight Ratio Materials for Propulsion System Components	M1, 2, 3, 4	C	----
o. High Performance Structures for Large Launch Vehicles (Submitted to Structures Technology Group)	M2	C	(a)
p. High Performance Structures for Large Launch Vehicles (Submitted to Structures Technology Group)	M2	C	(a)
q. Composite Engines Technology	M2	C	(a)
(2) <u>Solid</u>			
a. Low Cost Solid Rocket Booster	M2	C	(a)
b. High Performance Solid Kick	M3, 4	B	(b)
c. High Performance Space Solid Motors	M4, 5	B	(b)
B. <u>Metastable States of Matter</u>	O	D	(b), (c)
C. <u>Utilization of Indigenous Materials for Propulsion</u>	O	C	(b), (c)
D. <u>Detonation Propulsion</u>	M5, 6	C	(b), (c)
II. <u>Nuclear Propulsion Technology</u>			
A. <u>Fission</u>			
(1) <u>NEP</u>			
a. Nuclear Electric Propulsion Power Plant	M1, 3, 4	C	(c)
1.) Metallic-Fluid Heat Pipes (Submitted to Thermal Technology Group)	M1, 3, 4	C	(c)
2.) High-Performance Thermionic Conversion (Submitted to Power Technology Group)	M1, 3, 4	C	(c)
b. High-Power Electrostatic Thrust Subsystem	M1, 3, 4	C	(c)

[redacted]

	Technology (1) Driver	Technology (2) Readiness Code	Major (3) Thrusts Code
c. MPD Thrust Subsystem Technology	M3	D	(c)
(2) Direct Heating			
a. Solid Core Nuclear Rocket Technology	O	D	----
b. Fluid Core Nuclear Technology	O	D	(c)
c. High Temperature Plasma Core Reactor Fluid Mechanics (Submitted to Basic Research Technology Group)	O	D	(c)
B. Fusion			
Nuclear Fusion Propulsion Technology	O	D	(c)
C. Radioisotopes			
Combined Radioisotope Thermo-electric Propulsion Module	M1, 4	B	----
III. Collected Energy Technology for Propulsion			
A. Coherent Energy (Laser, Microwave)			
1.) Laser Heating of Propellants	O	D	(b)
2.) Laser and Microwave Electric Propulsion	O	D	(b)
B. Solar Electromagnetic Energy			
1.) Electric (Photovoltaic, Dielectric Concentrator/Heat Engine/Generator)			
a. Auxiliary Electric Propulsion With Hg Bombardment Thruster	M1	B	----
b. Solar Electric Primary Propulsion Thrust Subsystem	M1, 3, 4	B	(b), (c)
c. Electric Propulsion with Low-Molecular Weight Propellants	M1, 3	B	(b), (c)
2.) Solar Concentrator/Thermal Heating			
Solar Heated H_2 Propulsion	M3	C	(b)
3.) Solar Sails (Submitted to Structures Technology Group)	M4	C	----

1.) Technology Driver Code

M - Mission Driven Technology

1. On-orbit operations
2. Earth to low Earth orbit (LEO)
3. LEO to geosynchronous orbit or escape velocity
4. Interplanetary transport
5. Extraterrestrial landing, takeoff

O - Opportunity Driven Technology

2.) Technology Readiness Code

A. In use (Pre-1975)

B. Near term (1975-1985)

C. Far term (1985-2000)

D. Conceptual (post 2000)

3.) Major Thrusts Code - Reduce Space Transport Costs for:

a. Earth to LEO from 500 $/kg to 50 $/kg

b. Earth to GSO orescape from 3000 $/kg to 500 $/kg

c. Earth to Outer Reaches of the Solar System from 3,000,000 $/kg to 3000 $/kg

The accompanying table of Candidate Space Experimental Payloads summarize the suggested propulsion experiments.

TABLE OF CANDIDATE SPACE EXPERIMENTAL PAYLOADS

Space Payload Justification Categories
I. Space Environment Essential
II. Space Experiment Most Cost Effective
III. Space Demonstration to Reduce Risk

No.	Title	Justification Category
E1	Spacecraft Charing and High Voltage Interactions with Plasma (submitted to Power Technology Group)	I
E2	Flight Test of [illegible]-cm Bombardment Thruster	I
E3	High Temperature Plasma Core Reactor Fluid Mechnics (low-g) (submitted to Basic Research Technology Group)	I
E4	Vibration Test of Solid Rocket Motors	I

No.	Title	Justification Category
E5	The Storage Supply and Transfer of Cryogenic Fluids in Space (submitted to Thermal Control Group)	I
E6	Propellant Management Device Design Parameters at zero-g	I
E7	Thruster Induced Back Contamination	I
E8	Supercritical Combustion Measurements in zero-g	I
E9	Pulse Characteristics of Small Thrusters	I
E10	Flight Test of Composite Engine	I
E11	Deployment/Assembly and Control of Large Space Propulsion Energy Sources (Solar Sails, Solar Energy Concentrators, Solar Photovoltaic Panels)	I
E12	Sublimation Properties of Solidified Propellants	I
E13	Flight Test of SEP Thrust Subsystem	II, I
E14	Flight Test of Low Molecular Weight Propellant Bombardment Thruster	II
E15	Space Storability of Solid Rocket Motors	II, III
E16	Measurement of Solid Rocket Motor Thrust Alignment	III
E17	Final Qualification Test of N_2H_4 Resistojet	III
E18	Final Qualification of F_2/N_2H_4 Propulsion System	III
E19	Final Qualification Test of Cesium Ion Engine	III

SYNOPSIS

STRUCTURES AND DYNAMICS

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page 49

INTRODUCTION

This document contains a brief description of the final report of the Structure and Dynamics Technology Panel. The prime objective of the panel was to identify the structures and dynamics technology areas that need to be developed in order to carry out future activities in space. The areas were identified as Mission Driven or Opportunity Driven. Also identified were areas where utilization of the STS for experimentation in space could significantly enhance the development of the technology.

The technology areas identified correspond to the titles of the sections following the summary. Each section includes a page describing the objectives of the technology area, the scope, justification, and approach. In each section also are technology requirement forms and future testing and development requirement forms.

SUMMARY

The procedure used to define the structural requirements, technology needs and payloads is shown schematically in Figure 1. The objectives and missions in the OFS study were examined and critical missions requiring structures and dynamics technology determined. The 1973 Mission Model was used to provide additional input. Once the critical missions were known, the structural requirements for these missions were identified. Other technology panels and users were then consulted to determine if any critical missions or structural requirements were omitted. Technology areas, technical tasks, ground evaluation and payload definition were then defined for each structural requirement.

The working group also examined present and future research developed along disciplinary lines and forecast those technology improvements that could provide opportunities to either perform missions now impossible or more efficiently. Technology areas that meet this criteria were referred to as Opportunity Driven technology.

The principal technology driver for most missions and objectives was found to be Large Area Space Structures (LASS). Three categories of LASS were identified: antennas, solar array structures and platforms. Figure 2 shows examples of these. One of the largest structures required is a solar array for a solar power station whole total area is 50 square kilometers. In addition to large area structures, several missions required a long, slender structure or beam. This type of structure would be used either to support large objects from the shuttle or hold two bodies apart in space. Astronomy (OSS) has the most stringent requirement for such a structure; the maintaining of two bodies 100 - 1000 meters apart with an accuracy of one centimeter and a knowledge of their position to ten microns.

The Opportunity Driven technology needs consisted of advanced composite structure including minimum gage concepts and high temperature components, load and response determination and control, and reliability and life predictor. Advanced composites are needed by future space transportation systems and payloads for cost-effective weight reductions. Due to the high cost and weight sensitivities of spacecraft, accurate and reliable life prediction are mandatory.

The principal conclusion of the Structure and Dynamics Technology panels was that the most critical structural requirement for the achievement of the important objective of OFS is the timely development of large erectable space structures. Three major thrusts needed to accomplish this task were defined.

1. Develop and verify erectable structures technology for large (1 km) space structures by 1985.
2. Develop composites technology to provide a weight savings of 30% to 50% in LASS.
3. Experiments to verify erection techniques for large -^ructures in orbit.

The LASS technology needs were divided into six general categories:

(1) For the short term, large aperture deployable antenna structures have to be developed. This technology will be applicable to currently planned mission in which relatively small size structures are required. For large structures, erectable concepts are needed. In order to provide the technology for erectable structures, efforts in several technology areas must be initiated.

(2) Erectable structures concepts must be defined. This includes: the development of basic structural elements or building blocks that can be efficiently packaged into the Shuttle blocks that can be efficiently packaged into the Shuttle bay; determination of the configurations that result in the most effective assembly of the building blocks; and development of methods of assembly and fabrication in space.

(3) Techniques for actively controlling and stiffening the structure must be developed to achieve the high precision needed for effective use of antenna structures.

(4) Thermal distortion free structural concepts must be developed through the use of materials, designs, fabrication, and control techniques that will achieve structural assemblies that are dimensionally insensitive to change in the thermal environment.

(5) The feasibility of integrated systems concepts in which component elements of the structure and system perform multi-disciplinary functions of structure, thermal control and electrical conduction must be evaluated.

(6) Improved analytical procedures have to be developed that will permit the integration of all subsystem analyses so that interactions between subsystems can be accurately evaluated and trade-off studies can be performed.

The payload description of the LASS of necessity is general in content. The technologies are entirely new so that a considerable amount of structural system studies, analyses and ground tests are needed to define the limits of technologies, the specific configurations of interest, and verification tests required.

The following in-space tests are essential to developing technology to meet the needs for future space activities.

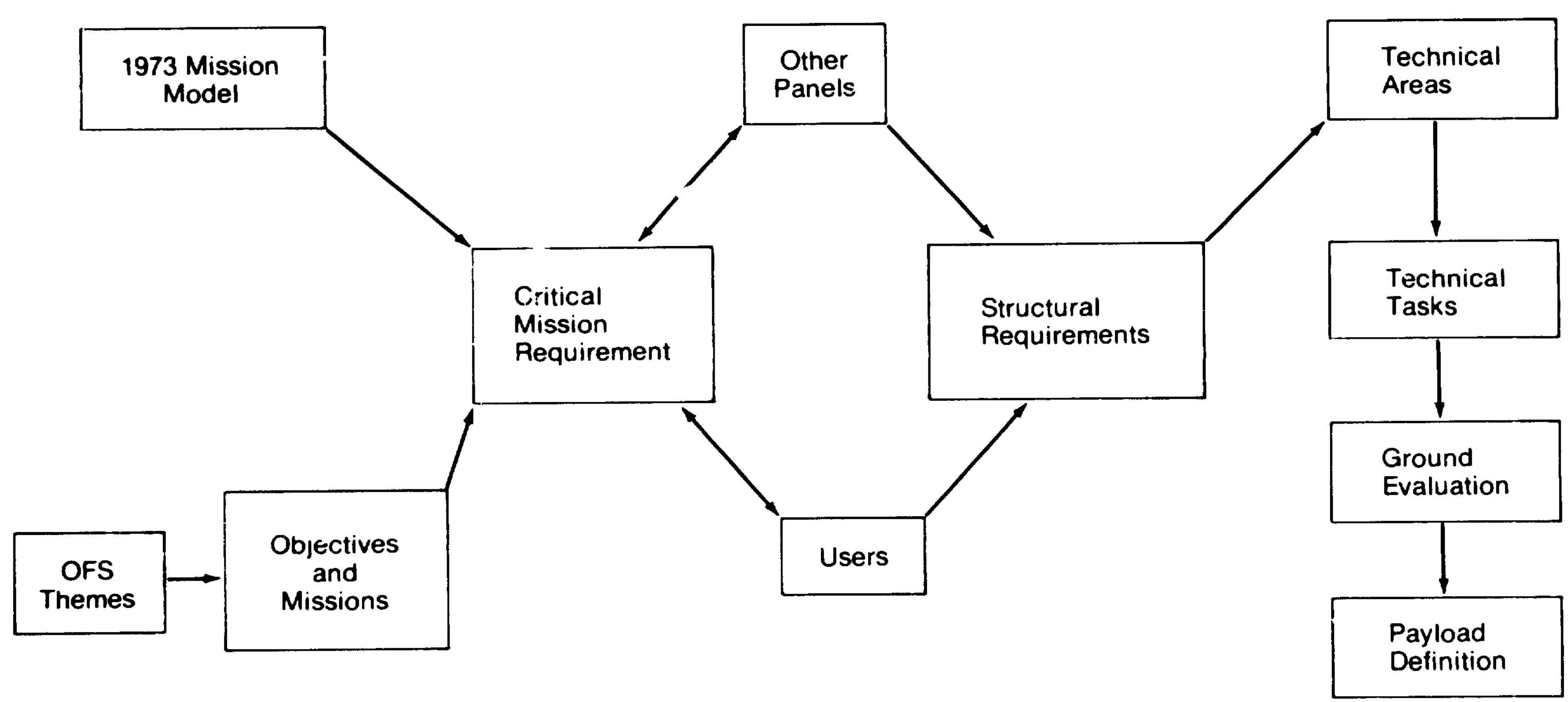
1. Large aperture deployable antenna structure demonstration.
2. Prototype large space structural element
3. Large erectable space structure - system development test
4. Actively controlled/stiffened structure feasibility test

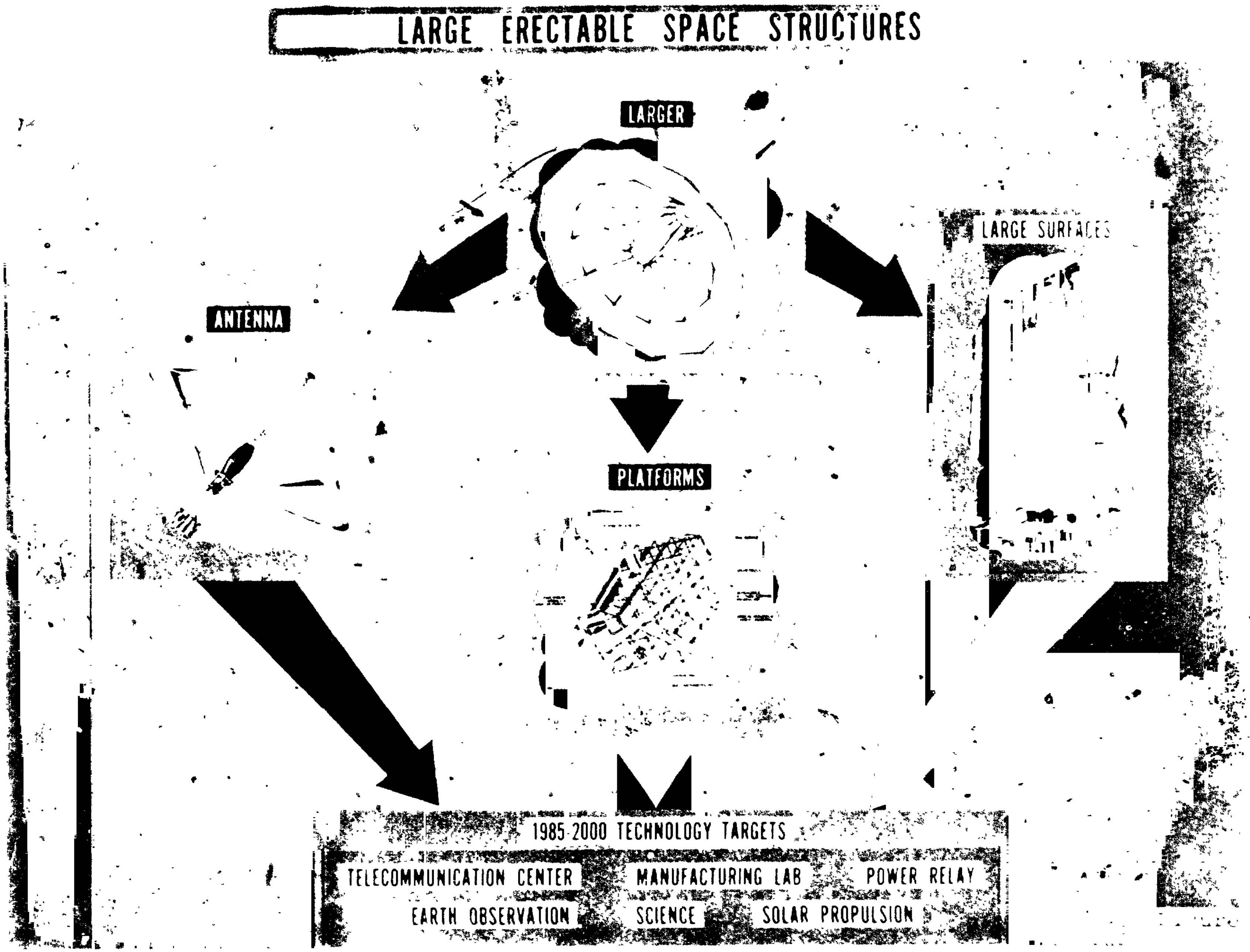
Other important tests are:

5. Thermal distortion-free structures demonstration
6. High-Temperature Polyimide Composite Shuttle Flight Experiment
7. High-Temperature Metal Matrix Composite Shuttle Flight Experiment
8. Long slender space structure

9. Space application of non-destructive evaluation
10. In-space development of inspection process
11. Shuttle bay dynamic evironment measurement
12. Shuttle orbiter load alleviation experiment

Fig. 1: STRUCTURES AND DYNAMICS PANEL - APPROACH




LARGE ERECTABLE SPACE STRUCTURES
LARGER
ANTENNA
PLATFORMS
LARGE SURFACES
1985-2000 TECHNOLOGY TARGETS
TELECOMMUNICATION CENTER
MANUFACTURING LAB
POWER RELAY
EARTH OBSERVATION
SCIENCE
SOLAR PROPULSION

SYNOPSIS

MATERIALS

VOLUME VII of XI

SUMMARY

The Materials areas as defined by this workshop is that which is pertinent to mission and flight experiment requirements for Structures, Power and Propulsion. Technology and flight experiment needs in other areas such as Thermal Control, Electronics, Entry Technology and Life Support are included in those sections.

MISSION DRIVEN MATERIALS TECHNOLOGY

Most Materials Technology Requirements have been classified as mission-driven because, from a materials viewpoint, a mission demand can be defined in every case even for those cases for which the applications technology does not recognize the benefits. It is obvious that a large majority of applications devolve into materials problems. An equivalent statment may be that an important function of the materials community is to define the limits of performance of materials. These limitations are based, at any particular time, on the properties of the material of interest and a knowledge of development potential both in properties and other factors such as cost and availability. Alternate materials and their potential improvements are also a factor.

The Materials Technology Requirements have been classified in two ways. First, the separation has been according to materials class; namely, Metals, Ceramics, Polymers, and Composites. The polymer classification also includes organic compounds research and development in areas such as lubricants and organic super-conductors. The second grouping, within each of the above classifications consists of Development, Characterization, Manufacturing and Basic Research. The compilation of Technology Requirements in this section is in accord with the above classification. Each requirement is further identified with key words that indicate reference to Structures, Power and Propulsion as well as to other pertinent areas.

Development is defined for the purpose of this report as the improvement of known materials and the synthesis of new materials using known phenomena and techniques. Characterization is the accumulation of property and environmental data necessary to predict whether a developed, available material will fulfill a certain mission requirement and whether it can be used with confidence by designers. Manufacturing refers to the process techniques which are required to produce a material in a form which is useful in a mission.

Topics in the Basic Research area resulted from considerations of two kinds. One was the recognizable needs for basic understanding that stem from the developments and applications that are foreseen for particular materials, e.g., composites and catalysts. The second consideration was the recognizable needs for advancement of understanding in the various areas of solid state physics, physical chemistry and others that directly pertain to materials development and applications. Examples are diffusion in alloys and the physics and chemistry of surfaces.

OPPORTUNITY DRIVEN MATERIALS TECHNOLOGY

Space processing of materials has been taken to be opportunity driven. It is designed to satisfy one of several requirements:

1) To supply data unobtainable on the ground
2) To run demonstrations for design purposes
3) To manufacture materials under conditions unobtainable on the ground
4) To manufacture or process materials in space for space use (possibly in the future from new materials obtained in space)

The ability to operate effectively in the low gravity environment of near earth orbit has provided a unique opportunity to do new materials research. The low gravity aspect of the environment in particular has excited interest in a host of new materials possibilities such as: containerless solidification and handling (levitation) for materials whose development on earth have been limited by reaction with containers, dyes, and molds; reduced convection in liquids leading to better control of the solidifying interface; and mixing of otherwise immiscible materials because of the elimination of density driven stratification. Research in the low gravity environment will lead to a better understanding of basic materials phenomena which are currently thought to limit earth-bound processing. It will also lead to manufacturing in space where the economic trade-off with transportation and energy requirements permit.

Studies on materials processing in space have been going on for several years. This work has been supported by the Office of Applications in NASA, but much of the emphasis has been on capitalizing on current flight opportunities and rapid pay-off. These flight experiments have indicated that more extensive ground based preparations and several iterative flight and ground experiments are needed to understand the problems involved in order to achieve the expected results. At this juncture, OAST needs to become involved in planning and directing the longer range development program on a larger scale.

Materials processing in space is divided into three areas: (a) development of commercially desired products needed in the industrial market (such as improved semi-conductors), (b) exploitation of the environment in performing basic research to improve the understanding of materials phenomena (such as solidification) which have a more distant pay-off, and (c) manufacturing and assembly in space to support missions such as solar energy stations which require the forming, erection, joining and repair of structures in space. Area A will continue to be supported by the Office of Applications. Tasks in areas B and C are proposed in the final report Volume VII, Materials Technology Panel Report.

CONTENT OF THE BODY OF THE MATERIALS WORKING PANEL PORTION OF THE REPORT

The Space Materials Technology Requirements identified by the working panel are attached. These have been divided into several categories. A narrative description was proposed on all items identified. A total of 52 items were included, broken into Mission Driven (48 requirements) and Opportunity Driven (4 requirements). In addition, those items for which a flight experiment was proposed were included again. A total of 27 candidate flight experiments were proposed. The need to index the topics was addressed as follows. A list of the titles of each narrative is attached. Further, a number has been assigned to each narrative and index and a cross index has been prepared on the basis of a discipline matrix and of a discipline/ application matrix.

SPACE MATERIALS TECHNOLOGY REQUIREMENTS
Mission Driven

Materials with High Thermal Conductivity and High Strength or High Temperatures for Rocket Motor Nozzles

Higher Temperature Superconducting Materials

Lunar Extractive Metallurgy

Environmental Interactions - Meteoroids and Radiation

Refractory Alloys

Fracture Toughness/Strength Optimization of High Strength Structural Alloy Systems

Utilization of Magnesium, Beryllium and Beryllium-Aluminum Alloys in Advanced Space Structures

Low Cycle Thermal Fatigue of Superalloys

Fatigue, Fracture and Life Prediction of Metallic Structures Exposed to Chemical Environments

NDT/NDE - Earth and Space

Development of Elastic-Plastic Failure Criteria

Solar Cell Solder Connections with Extended Life During Thermal Cycling in Orbit

Joining Metals in Space

Basic Studies of Electromigration in Metals and Alloys

Theoretical Studies of Diffusion in Alloys

Basic Studies in Catalysis

Basic Studies of Mechanisms of Hydrogen Embrittlement

Basic Studies of New Concepts for Solar Cells

Solid State Diffusion Studies in Space

Experimental Studies of Diffusion in Alloys

Phase Diagram Studies in Space

Measurement of Vapor Pressure of Corrosive Materials

High Temperature Insulations

Structural Ceramics

Ceramic Fibers for Composites

Large Area Polymer Films for Space Applications

Adhesive Bonding of Large, Erectable Structures in Space

Long Life Polymeric Protective Coatings for Space Applications

Long Life Adhesives for Space Applications

High Temperature, High Thermal Conductivity Polymeric Materials

Improved Electrical Conductivity Polymeric Materials

Retention of Liquid Lubricants "in Place" Under Dynamic Conditions

Retention of Liquid Lubricants by Passive Means Under Passive Conditions

Effects of the Space Environment on the Properties of Specific Polymeric Materials

Space Repair of Polymers in Electronic Assemblies

Basic Studies of the Relation Between Molecular Structure and Mechanical Behavior of Polymers

Basic Studies of Polymer Matrix Composite Structure Behavior

Basic Studies in Electrochemistry

Physics and Chemistry of Organic Superconductors

Composite Materials with Low Coefficients of Thermal Expansion

Standardization of Composite Materials Processing and Testing

Effect of Long Duration Space Exposure on Properties of Composite Materials

Characterization of Damage Mechanisms Associated with Failure and Degradation of Composite Materials

Manufacturing of Composite Materials in Space

Development of Joining, Inspection and Repair Methods for Erectable Structures in Space

Basic Solid State Physics of Metal Matrix Composites

Studies of Creep and Fracture Mechanisms in Composites

Sub Total <u>48</u>

SPACE MATERIALS TECHNOLOGY REQUIREMENTS
Opportunity Driven

Development of Directionally Solidified Eutectic Compounds in Space

Containerless Casting and Shaping Reactive Metals in Space

Fabrication and Assembly of Materials for Large Structures in Space

Space Processing of Ceramics and Glass

Sub Total 4

The in-space experiments considered crucial for future needs and developments are listed below:

1. Develop Directionally Solidified Eutectic Compounds in Space

2. Processing and Use of Chemically-Active Metals in Space

3. Containerless Casting and Shaping of Reactive Metals in Space

4. Fabrication, Assembly and Joining of Materials for Large Space Structures

5. Refractory Metal Heat Pipes

6. Solid-Solid Metal Embrittlement in the Space Environment

7. Influence of Long Term Space Exposure on Localized Plasticity in Metals

8. NDT/NDE - Earth and Space

9. Refractory Metal Contamination

10. Light Metal Alloys - Long Time, Low Earth Orbit Exposure on Mechanical Stability

11. Joining Metals in Space

12. Solar Cell Solder Connections with Extended Life During Thermal Cycling in Orbit

13. Solid State Diffusion Studies

14. High Temperature Vaporization Studies of Corrosive Molten Salts

15. Phase Diagram Studies at Low Pressure and Zero-G

16. Space Processing of Ceramics and Glass

17. Long Life Polymeric Protective Coatings for Space Applications

18. Long Life Adhesives for Space Applications/Solar Cells, Thermal Tapes, Honeycomb, etc..

19. High Temperature, High Thermal Conductivity of Polymers for Space Applications

20. Effects of the Space Environment on the Properties of Specific Polymers

21. Improved Electrical Cc ductivity of Polymers for Space Application

22. Retention of Liquid Lubricants by Passive Means in The Space Environment Under Passive Conditions

23. Retention of Liquid Lubricants "in Place" Under Dynamic Conditions Using Barrier Films and Labyrinth Seals

24. Space Repair of Polymers in Electronic Assemblies

25. Long Term Space Exposure of Composite Materials

26. Effects of Space Environment Effects on Fatigue and Fracture of Advanced Filamentary Composite Structural Materials

27. Adhesive Bonding of Large Erectable Structures in Space

SYNOPSIS

THERMAL CONTROL

VOLUME VIII of XI

INTRODUCTION

The technology recommendations in Volume VIII of the final report were developed during the two-week NASA/OAST 1975 Summer Workshop, based on the background information provided and the expertise of the working group members. The supporting text and technology descriptions are intended to contain sufficient information to permit assessment as required.

In Volume VIII the technology requirements (Section II) are not intended to be a complete listing, and the relative scope of Sections II and III (flight experiments) should not be construed to indicate the relative importance of ground based technology versus space experiments. Identification of technology requirements was an essential and accomplished step in defining meaningful space experiments. Since the primary objective of the Workshop was the identification of space experiments, priority was given to their documentation for the final report.

For the purposes of dealing with the total of thermal control technology, several technology categories were identified. These categories included both the requirements as well as specific tools or means to meet these requirements. The sequence has no relation to relative importance, but merely provided a convenient means of organization.

In defining flight experiments, the primary criterion was the need for space (i.e., low-g, vacuum, etc.). The question of relative cost of space vs. ground testing could not be addressed due to the constraints of time. Some technology items not included in the report may become candidates for space experiment if cost effectiveness can be shown.

The working panel undertook to define its scope, starting with the Outlook for Space (OFS). Thermal control has been defined by OFS as Management of Matter (maintenance of state). During the initial establishment of an approach, some technology items were not clearly identified. These included contamination, radiation and micrometeorites. The containment of pressurized fluids dealt only with thermal control materials (cryogens and phase change materials) aspects of the problem. In the area of contamination, the working panel considered only the effects of contamination on the properties of thermal surfaces and some of the effects of temperature profile on contaminant transport.

Technology related to radiation effects on thermal surfaces was included. All other aspects of radiation (i.e., model definitions, other effects, etc.) were deleted from consideration. Micrometeroid technology was omitted. The potential significance of the above omissions is discussed in more detail in Appendix C of Volume VIII.

Thermal control design requirements and constraints are derived from the specifics of mission, system, and subsystem design. These design drivers are typically not well defined for advanced missions, with the result that the associated requirements for thermal technology which are interactive with other features of spacecraft design, have consequently been omitted from the Thermal Panel's considerations. This omission was the undesirable but unavoidable result of not being able to define part of the required input data; the process of identifying candidate technology developments and flight experiments can be expected to proceed as these data become available. The recommendations herein should therefore be understood to be incomplete in this important area.

SUMMARY

Since the Thermal Control Panel had just recently completed a near term assessment of their technology needs, the panel was able to concentrate on long range identification of technology requirements. The Outlook for Space, Forecast for Technology, was used as a primary reference for identifying anticipated long range technology deficiencies. Furthermore, the overriding themes which were apparent during the workshop were large structures and cold controlled environments. The Thermal Control Panel has attempted to address its technology forecast in the perspective of these guidelines.

Thermal Control technology was divided into eleven categories: Thermal Control Surfaces; Heat Pipes; Mechanisms; Testing; Instrumentation; Contamination; Cryogenics; Analysis; Thermal Properties; Insulation; and Design Techniques. These categories include both technology requirements and tools. Particular long range needs were identified under these categories and finally, relevant flight experiments were identified and documented.

Three major thrusts, besides reduction of costs, were identified as major directions for thermal control technology development and space experiments.

(1) Extend the useful lifetime of cryogenic systems for space.
(2) Reduce temperature gradients.
(3) Improve temperature stability.

The cryogenic objective is interpreted to include such elements as methods for achieving temperatures approaching $0^\circ K$, cryogen management, passive radiation and refrigeration systems for replacing expendable cryogens, and technology for cryogen replenishment as well as devices and systems designs to extend lifetime directly by reducing losses.

Reduction of a macro-gradients (tens of degrees) in very large structures and micro-gradients (degrees and fractions of degrees) in instruments and optical systems or the effects of such gradients will be achieved by combinations of new technology in thermal control surfaces, material properties and design approaches as well as active devices, such as heat pipes. For example, thermal distortion of an antenna might be reduced by use of low coefficient of expansion material for construction, thermal expansion compensated configuration or heat pipes as ribs.

Improved temperature "stability" includes improved ability to achieve a required absolute temperature, accurate prediction of equilibrium operating temperature in space, controlled transient temperatures as well as ability to maintain acceptable temperatures under varying load and lifetime conditions. Technology requirements include active devices and systems, design approaches as well as long term properties and stability of coatings, insulation, etc..

A consensus of the five key flight experiments was not taken by the panel. However, the chairman has identified four key experiments and the fifth experiment will depend on whether space processing and power experiments or earth resources and earth science experiments are given priority.

The key experiments are:

(1) Shuttle Contamination Effects on Thermal Control Surfaces
(2) Stored Cryogen System Evaluation
(3) He II Storage and Utilization
(4) Ultra-high Conductance Heat Pipe Development for Very Large Structures

For space processing and/or power experiments, the fifth experiment should be:

(5) Development of Large, Variable Heat-rejection Radiators

For earth resources and earth science experiments, the fifth experiment should be:

(5) Development of a Deployable, Controlled Orientation Radiator

The following is a more complete listing of experiments identified by the panel:

1. Thermal Control Materials Compatible with the Space Plasma Charging Environment
2. Improved Temperature Control Coatings For Very Large Space Structures Including Solar Collectors
3. Evaluation of Long-Life Stability of S/C Thermal Control Surfaces
4. Repair/Refurbishment of Thermal Control Surfaces in Space
5. Adhesives for Attachable Thermal Control Surfaces
6. Cryogenic Heat Pipe Radiative Coolers
7. Ultra-high Thermal Conductance Heat Pipes
8. Improved Solid Cryogenic Lifetime Experiment
9. Precision Temperature Control Techniques Using Heat Pipes
10. Large Variable Heat Rejection Radiators
11. Phase Change Materials for Thermal Storage
12. Expendable Materials Heat Rejection Systems
13. Deployable/Orientable Radiator Systems and Components
14. Temperature Control Device Test Facility
15. Zero-G Measurement of Heat-Pipe Disturbances
16. Scalable Shuttle-Launched, Free-flying Facility for High Power Density Testing
17. Effects of Shuttle Induced Contamination of Thermal Control Surfaces
18. Techniques for Contamination Protection
19. Liquid Cryogenic Transfer
20. Liquid Cryogen Storage and Supply
21. Joule-Thomson Expansion of Supercritical Helium
22. Transfer of Cryogens Across Gimbals
23. He II Storage and Utilization
24. $^3He/^4He$ Dilution Refrigerator - Operable in Zero-G
25. Magnetic Refrigeration - Demagnitization of Rare Earth Salts
26. Closed Cycle Helium Refrigeration Unit

SYNOPSIS

ENTRY

VOLUME IX of XI

INTRODUCTION

This document contains a brief description of the final report of the Entry Technology (ET) Panel. The Entry Technology Panel surveyed the available inputs such as the 1973 NASA Mission Model, the Outlook for Space document and various user requirements; and based on these, made recommendations for technology advancements through the use of the Space Transportation System.

Two major objectives have been identified that will insure that the technology requirements will be achieved. These objectives deal with the establishment of heatshield and aerothermodynamic technology for (a) an Advanced Space Transportation System Heavy Lift Orbiter and (b) Hypersonic Atmospheric Entry Missions.

Two minor objectives were also identified and are (c) the development of an emergency astronaut "life boat" and (d) basic research in boundary layer transition.

Specific payloads are identified in the report supporting the major and minor objectives cited above. The majority of the payloads are shuttle based; however, a planetary entry payload to Jupiter is also suggested. The shuttle is to be utilized in three specific ways: First, as a payload deployment base for deorbit; secondly, through the use of the TUG or IVS; and thirdly, the orbiter itself will be instrumented.

Recurrent themes are (1) the unsuitability of ground based testing due to the inability to simulate proper test conditions and the resulting need for space testing and (2) the need for better mathematical models describing accurately and realistically the flow fields around complex structures.

Following this introduction, a summary is provided which expands on the above objectives.

SUMMARY

The Entry Technology Working Panel of the OAST Technology Workshop has surveyed the 1973 NASA Payload Model, the OSS Statement of New Technology Requirements, the Outlook for Space, results of studies carried out by the Entry Technology Study Team of the OAST Space Shuttle Technology Payloads Office and numerous other user requirements in order to make recommendations for technology advancements through the use of the Space Transportation System. It was found that the required technology advancements could be achieved by carrying out research within the two major objectives of establishing heatshield and aerothermodynamic technology for an advanced space transportation system (STS) heavy lift orbiter and for hypervelocity atmospheric entry missions.

The need for an advanced heavy lift orbiter was repeatedly emphasized in the Outlook for Space where it was pointed out that several highly desirable missions such as the space solar power station and nuclear waste disposal are feasible (from a cost standpoint) only if launch costs are significantly reduced by developing such a heavy lift orbiter. Furthermore, it was pointed out that many missions (such as those involving the assembly of large structures in space) which are feasible with the present shuttle, would be significantly benefitted by an improved shuttle, a second generation shuttle or an advanced lift orbiter.

Advancement of hypervelocity atmospheric entry vehicle technology is needed to allow increased payload fractions (scientific instrumentation) and broadened entry corridors for atmospheric probe, lander and sample return missions. This need is particularly great for missions to the giant planets (Saturn, Jupiter, Uranus) where presently designed heatshields account for 30 to 50 percent of the total entry vehicle mass. Advancements in this technology area are also required to assure earth re-entry survival of a nuclear waste capsule following a launch vehicle abort during a nuclear wast disposal mission. The working group has also identified the need for individual emergency entry capsule development (which would be particularly valuable for use with a space station such as that recommended in the Outlook for Space) and identified an opportunity to investigate the phenomena of boundary layer transition with small entry vehicles carried as "piggy back" payloads and launched from the space shuttle.

Regarding the establishment of heatshield and aerothermodynamic technology for the advanced STS orbiter, the working group has identified five technology requirements and nine payloads to satisfy these requirements. With regard to hypervelocity atmospheric entry, six technology requirements and five payloads were identified. One technology requirement and one corresponding payload were identified for the individual emergency entry capsule and opportunity driven boundary layer transition research respectively. These technology requirements and payloads are listed in Tables I and II. The interaction of the technology requirements and payloads is illustrated in Table III where an "X" indicates the technology requirement to which each payload contributes. It should be pointed out that in selecting payloads, the working group only considered technology problems that could not be solved in ground-based test facilities. Hence, for the payloads and corresponding technology requirements considered in this report, the alternative of solving the problem in ground-based test facilities does not exist.

The Entry Technology panel recommends that the entry payloads definition studies be continued and that the technology requirements and payloads described in the present report be pursued in a manner which will result in technology readiness at the appropriate mission or project initiation date. In some cases these technology readiness dates are now known; however, many dates will not be established for some time. Further work and planning is required to determine a priority ranking for the several payloads in light of available resources, both funding and manpower.

TABLE I. Entry Technology Requirements

Mission Driven

(1) Advanced STS Orbiter 5
- Advanced STS Configuration
- Improved Thermal Protection Systems (TPS)
- Improved Mathematical Models for Complex Real Gas Flowfields and Ground-to-Flight Extrapolation
- Advanced Structures
- Boundary Layer Transition Criteria

(2) Hypervelocity Atmospheric Entry 7
- Planetary Entry Probe Heatshield and Configuration
- Nuclear Waste Disposal Package
- Radiative Flow Field Models
- Planetary Sample Return Heatshield and Configuration
- Manned Planetary Return Heatshield and Configuration
- Planetary Bouyant Station Deployment

Flight Demonstration: RGT Heat Source Survival	
(3) Individual Emergency Entry	1
Astronaut Retrieval	
TOTAL	13

Opportunity Driven

Basic Research	1
Prediction of Boundary Layer Transition	
TOTAL	1

TABLE II. Candidate Flight Payloads

(1) Advanced STS Orbiter	9
Orbiter	
Air Data System	
IR Camara-Lee/Windward Heating	
Instrumentad Test Panels	
Catalytic Surface	
Boundary Layer Transition Measurement System	
Deployed Payloads	
Advanced STS Configurations	
Integral Tank Configurations	
Advanced TPS Concepts	
Advanced Hypersonic Cruise Vehicle Configurations	
(2) Hypervelocity Atmospheric Entry	5
Entry Probe	
Nuclear Waste Disposal Package	
Lifting Body Entry Vehicle	
Bouyant Station	
RTG Heat Source	
(3) Individual Emergency Entry	1
Astronaut Retrieval	
(4) Basic Research	1
Boundary Layer Transition	
TOTAL	16

TECHNOLOGY REQUIREMENTS / PAYLOADS	ADVANCED STS CONFIGURATIONS	IMPROVED THERMAL PROTECTION SYSTEMS	IMPROVED MODELING EXTRAPOLATION PREDICTIONS	ADVANCED STRUCTURES	IMPROVED PREDICTION BOUNDARY LAYER TRANSITION
ORBITER (CARRIER)					
AIR DATA SYSTEM	X	X	X		X
LEE/WINDWARD HEATING IR		X	X		X
INSTRUMENTED TEST PANELS	X	X	X		
CATALYTIC SURFACE EXPERIMENT		X			
BOUNDARY LAYER TRANSITION	X	X	X		X
DEPLOYED PAYLOADS					
ADVANCED STS CONFIGURATION	X		X		
INTEGRAL TANK	X	X		X	
ADVANCED TPS CONCEPTS		X			
ADVANCED HYPERSONIC CRUISE VEHICLE	X		X		X

(a) Heat shield and aerothermodynamic technology for advanced STS orbiter

Table III: RELATION OF ENTRY TECHNOLOGY PAYLOAD TO TECHNOLOGY REQUIREMENTS

TECHNOLOGY REQUIREMENTS / PAYLOADS	IMPROVED PLANETARY ENTRY PROBE HEAT SHIELDS	SAFE NUCLEAR WASTE DISPOSAL CAPSULE/RTG	ACCURATE RADIATIVE FLOW FIELD MODELING	EFFICIENT PLANETARY SAMPLE RETURN HEAT SHIELD AND CONFIG-URATION	SAFE PLANETARY MAN RETURN HEAT SHIELD AND CONFIG-URATION	RELIABLE BOUYANT STATION DEPLOYMENT
ENTRY PROBE	X	X	X	X	X	
NUCLEAR WASTE CAPSULE	X	X	X	X	X	
LIFTING BODY ENTRY VEHICLE	X		X		X	
RTG HEAT SOURCE	X	X	X			
BOUYANT						X

(b) Heat shield and aerothermodynamic technology for hypervelocity planetary atmospheric entry.

Table III: RELATION OF ENTRY TECHNOLOGY PAYLOADS TO TECHNOLOGY REQUIREMENTS (cont.)

PAYLOAD ↓ / TECHNOLOGY REQUIREMENT →	SPACE PERSON/ PACKAGE RETRIEVAL
SPACE PERSON/ PACKAGE RETRIEVAL	XXX

(c) Heat shield and aerothermodynamic technology for individual emergency re-entry

PAYLOAD ↓ / TECHNOLOGY REQUIREMENT →	BOUNDARY LAYER TRANSITION
SMALL DEPLOYED VEHICLES	XXX

(d) Opportunity Driven Basic Research

Table III: RELATION OF ENTRY TECHNOLOGY PAYLOADS TO TECHNOLOGY REQUIREMENTS

SYNOPSIS

BASIC RESEARCH

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INTRODUCTION

NASA researchers, in concert with scientists from the academic community, have been focusing attention on the use of the space transportation system as a vehicle for conducting basic research. The primary thrust of these discussions has been the identification of experiments of high scientific merit which can benefit from being conducted in the unique environment offered by space. The latter refers to the convectionless conditions available in reduced gravity, the virtually unlimited pumping capacity available, as well as the upper atmosphere temperature, composition and radiative characteristics.

The results of these past studies were surveyed by the Basic Research Panel at the OAST Space Technology Workshop. Experimental areas in fluids, combustion, low density gases, simulation and gravity were consequently identified. The exercises involved in identifying fertile areas for experimentation were also productive in terms of recommending modus operandi. These experimental areas, as well as specific experiments, are described along with its justifications for the need to go into space and potential applications of the science to be generated. A modular philosophy in which classes of experiments are serviced by a single facility, the involvement of as many scientists as possible from outside NASA, and the time issuance of announcement of flight opportunity are the most important of these suggestions. A set of recommendations considered as the key to facilitate the maximum utility of the space shuttle system as a basic research tool was also provided.

SUMMARY

The Basic Research Panel directed their efforts toward: (1) identifying enabling basic research that would impact the experiment and technology requirements of the other (discipline) panels and the missions defined by the User Group; and, (2) identifying interesting basic research experiments which would be performed in space.

Enabling Basic Research

Enabling basic research requirements were obtained from solicitations from the discipline panels, from review of the Outlook for Space, the 1973 NASA Mission Model and various other reference documents and from discussions with members of the User Group. Over fifty specific discipline requirements were submitted and have been incorporated into the report without priority judgment under the following broad categories.

Discipline Panels'Needs

Materials
Surface Contamination
Fluids
Life Support
Instrument Development
Miscellaneous

In addition, from the User Group's stated mission needs, over seventy technology requirements were identified which would require prior basic research. These research areas are listed below in decreasing order of frequency of citation.

User Group (Mission) Needs

*Quantum Electronics: Lasers and Opto-Electronic Devices

*Cryogenic Systems Technology: Normal Cyrogens and Superfluid Helium
Remote Sensing
Nuclear Energy

*Photo-Induced Reactions
Fault Tolerant Theory
Artificial Intelligence
Solar-Electric
Failure Physics

*Bioengineering

*The Basic Research Panel carefully examined all the areas and, based on potential mission impact and urgency, recommended these to be areas of OAST emphasis (except Bioengineering, which is outside OAST purview).

It was recognized during the Workshop that not all panels submitted comprehensive research plans to the Basic Research Group. For this reason the group believes additional requirements, perhaps of more importance than those listed above, must be gleaned from the reports of the other panels. For this reason, the areas identified above should be viewed as a preliminary selection with more work needed for refinement.

Basic Research Experiments in Space

The Basic Research Panel examined potential basic research experiments in space by reviewing the output of previously OAST funded studies. Experiments were recommended which (1) use the unique environment of the shuttle and therefore cannot be performed on Earth, and (2) provide useful basic research information and in some cases have direct technological "fallout" into mission program needs.

The experiments, discussed in detail in Volume X of the final report, can be grouped into the following experimental areas:

Fluids
Combustion
Low Density Gases
Simulation
Gravity

In addition, the panel formulated recommendations aimed at reducing the experimental cost and enhancing the usage of the Spacelab by basic research scientists. These included (1) the use of dedicated modules in which a class of experiments (rather than one) would be performed and which would be made available for experimental usage by a Users Group, (2) the incorporation of remote experimental control to allow real time experimentation by ground-based scientists, (3) the provision of general purpose equipment such as a centrifuge, He II dewar, and mass sensor, (4) environmental mapping of the Spacelab for such things as noise and g-jitter so that sensitive experiments can be properly positioned and (5) the monitoring and logging of such environmental factors to allow later data interpretation.

SYNOPSIS

LIFE SUPPORT

VOLUME XI of XI

INTRODUCTION

The objective of the Environmental Control and Life Support Systems (ECLSS) Program is to conduct an orderly Research and Technology development program that will provide matured life support technology for selected future manned flight program objectives. Technology maturity must be achieved via an evolutionary process to ensure that condidate concepts are fully and logically evaluated and then adequately developed prior to selection of the final concept for any space opportunity being directed toward a specific mission application.

As previously noted, the cost of providing expendable items for the life support function becomes prohibitively expensive as mission duration increases; therefore, regenerable techniques must be employed. The program proposed here provides for the research and development of regenerative-class life support breadboard systems for laboratory testing and the development and checkout of integrated flight hardware. This study uses, as convenient focal points, successively ambitious future manned spaceflight opportunities as shown in Figure 1. The life support technology required for these opportunities shows increasing degrees of system closure as the NASA manned space program progresses in the future (see Figure 2).

The Life Support Program, outlined in this study, may be divided into two program categories: (1) A sustaining R&D program that is needed to provide the basic and applied research to supply new ideas, approaches and concepts, and necessary development of these to show feasibility and optimum application potential; and (2) the specific Life Support projects responsible for the further development, testing and integration into flight certified prototype hardware. This latter work is necessary to establish, both in ground tests and flight tests, the correctness and suitability of the system. Each succeeding manned spaceflight opportunity depends on previous accomplishments, both technical and programmatic. As an example, the final testing of a Mars Lander ECLSS is seen as being accomplished in near-Earth orbit and dependent upon an orbiting Space Base. Similarly, the first of the biological systems expected to be required for a permanent Lunar Habitat would first be set up and demonstrated in a reduced scale within a temporary Lunar Colony.

Work in other related areas of life sciences needs to be successfully accomplished in addition to the life support and protective systems for these future missions. This includes other disciplines within the Office of Life Sciences such as medical, physical, psychological considerations and requirements, man-machine relationships and social group dynamics. Advanced space suits and protective systems will play an important part in the success of these future missions. Advanced EVA capability will be required in order to provide for contingencies and to enhance man's capability for deploying and servicing payloads, erecting large structures and to minimize space payload costs.

Volume XI of the final report has been prepared by NASA personnel whose expertise is mainly in the area of life support concept and hardware development. Therefore, this volume concentrates on life support and crew equipment facets and not on behavioral sciences and other facets of man's relationship to the space environment. There are, however, ongoing activities in these areas as a portion of the overall NASA Life Sciences Program. In fact, studies are being performed to define specific Spacelab experiments to be flown as dedicated Life Sciences payloads in accordance with "the 1973

NASA Payload Model".

The methodology used in arriving at the results of this workshop study is shown in Figure 3. Additional factors and limitations to the study compiled by the OAST Workshop Life Support Panel are:

1. Life Support functions and supplies obtained from manufacturing processes or from extraterrestrial raw materials have not been considered.

2. Transportation costs necessary to use life support equipment in space either as an experiment or for producing a habitable environment on-board a spacecraft have been excluded from resource forecasts.

3. Pollution control for extraterrestrial colonies and habitats has not been considered as a life support system function.

4. No unforeseen breakthroughs in life support technology have been considered to occur during the time period considered in the technology forecast.

5. Resource forecasts have been made on the basis of 1975 dollars.

For purposes of the final report, life support technology has been subdivided into two main classes: (1) Physico-Chemical ECLSS Systems; and (2) Biological Life Support Systems. The various systems are described in one section of Volume XI of the final report.

Another section discusses a forecast for technical advancements in terms of projected manned space flight opportunities, including anticipated flight experiments.

SUMMARY

Life support technology advancements in terms of system closure and regeneration capability were analyzed for a variety of manned space opportunities. It has been determined that regeneration capabilities must be developed in a step-wise fashion through space flight experiments and continued SRT supported R&D to meet the succession of increasingly ambitious space opportunities. In particular, SRT supported development of biological type life support systems must be implemented for the realization of long term space goals.

Regeneration and system closure have been shown to be dependent on mission duration, spacecraft crew size, cost of resupply and spacecraft power source. The evolution of life support technology must include water recovery, oxygen recovery, waste management recycle and, ultimately, a man-made closed ecology with selected biological species before large-scale permanent space habitation can become possible. A NASA Life Sciences dedicated regenerative ECLSS experiment has been identified in the workshop study as a necessary precursor to the flight certification of regenerative capabilities necessary for a Space Station. Other possible life support experiments that are needed for other space opportunities have been identified as:

-Water recovery (vapor compression distillation)
-Water electrolysis (solid polymer electrolyte)
-Nitrogen generator
-Crew appliances
-Solid waste management
-Microbiological/plant/animal experiments

Basic research needs were identified to be:

-Identify purity standards, methodology and measurement techniques for establishing "safe" water
-Identify manned spacecraft air quality standards
-Identify effects spacecraft contamination on optical sensing devices
-Identify cleanliness standards for long duration space mission crewmen

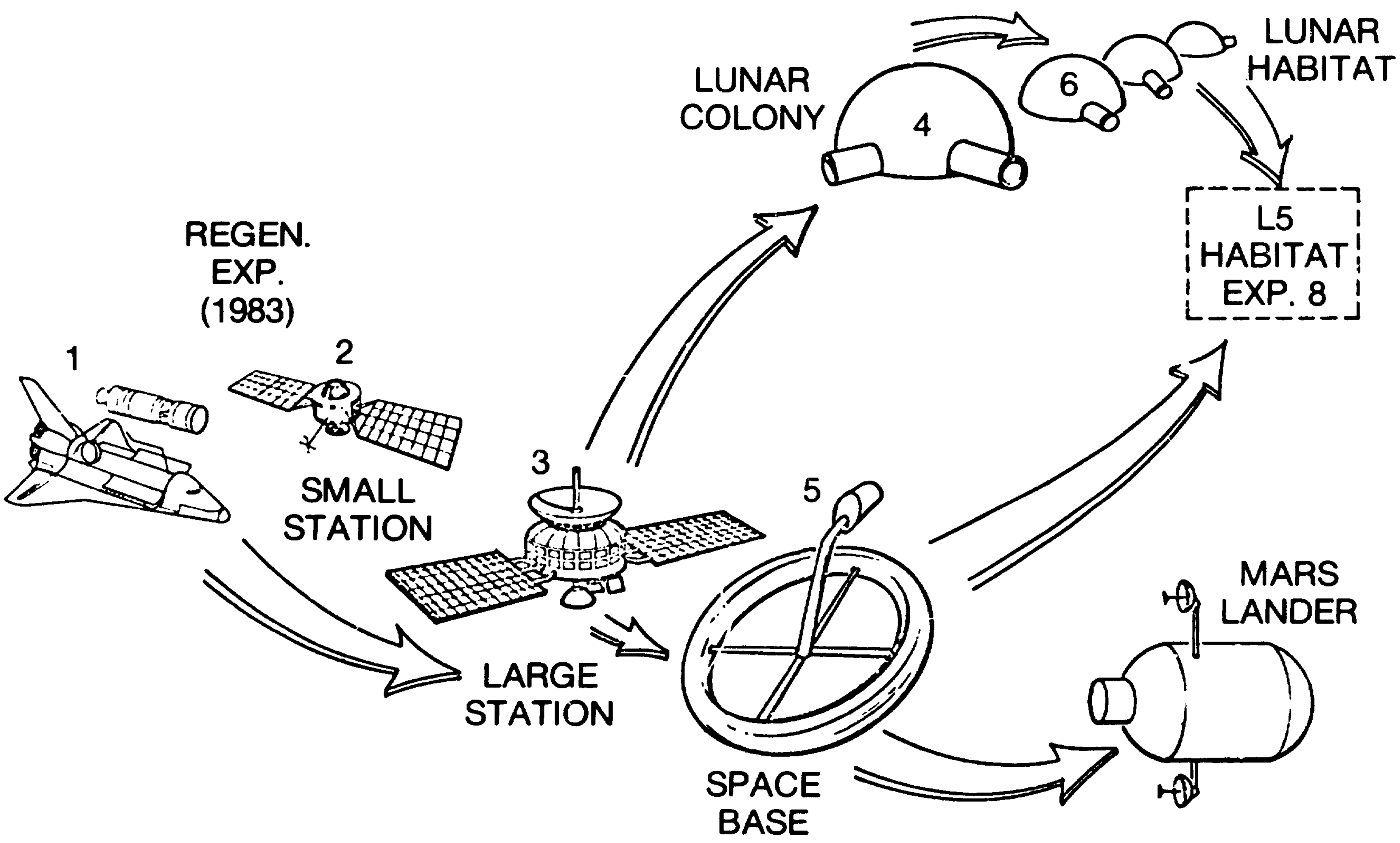

REGEN.
EXP.
(1983)
1
2
SMALL
STATION
3
LARGE
STATION
LUNAR
COLONY
4
6
LUNAR
HABITAT
L5
HABITAT
EXP. 8
5
SPACE
BASE
MARS
LANDER

FIGURE 1

Fig. 2: TECHNOLOGY THRUSTS

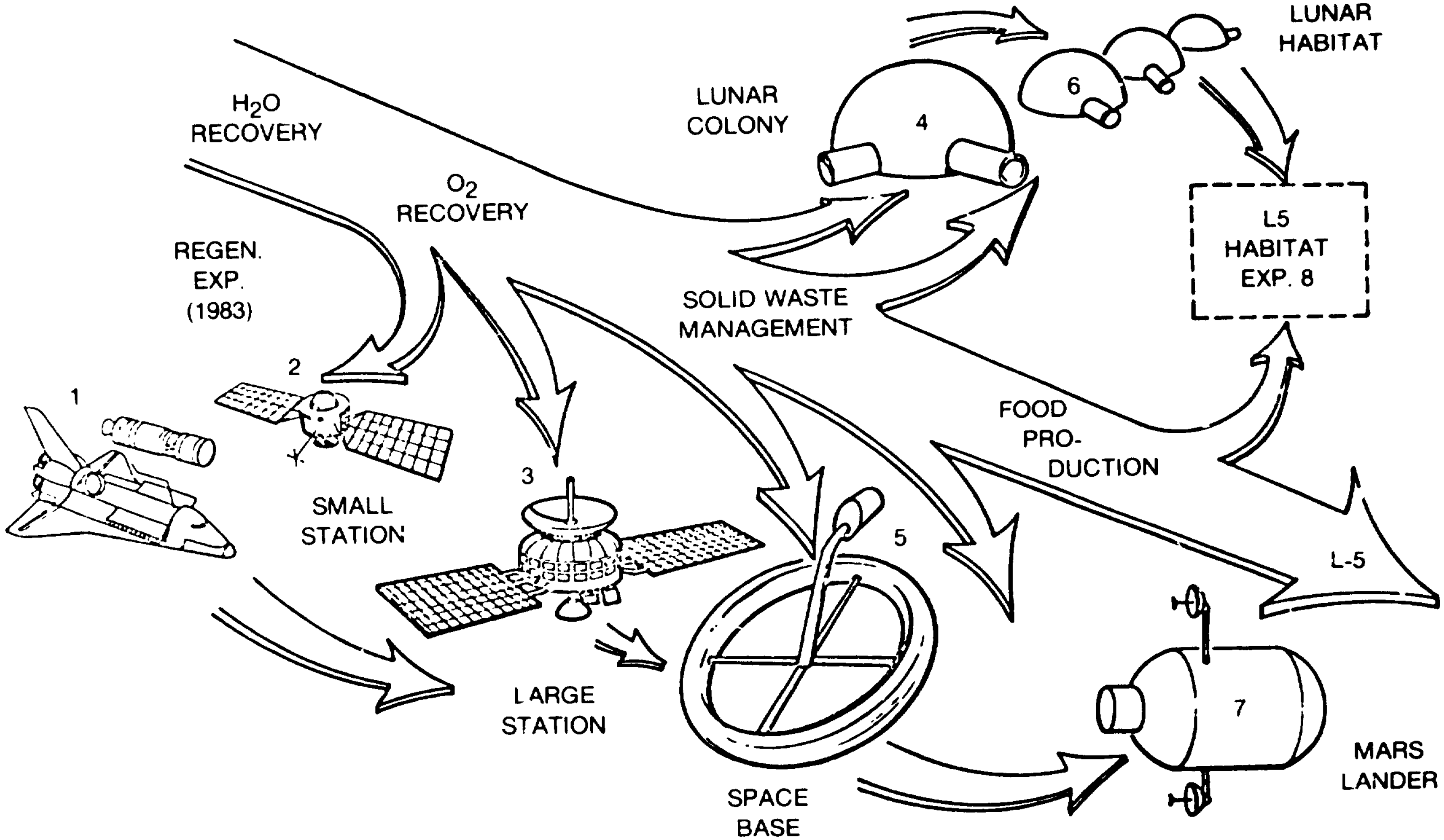
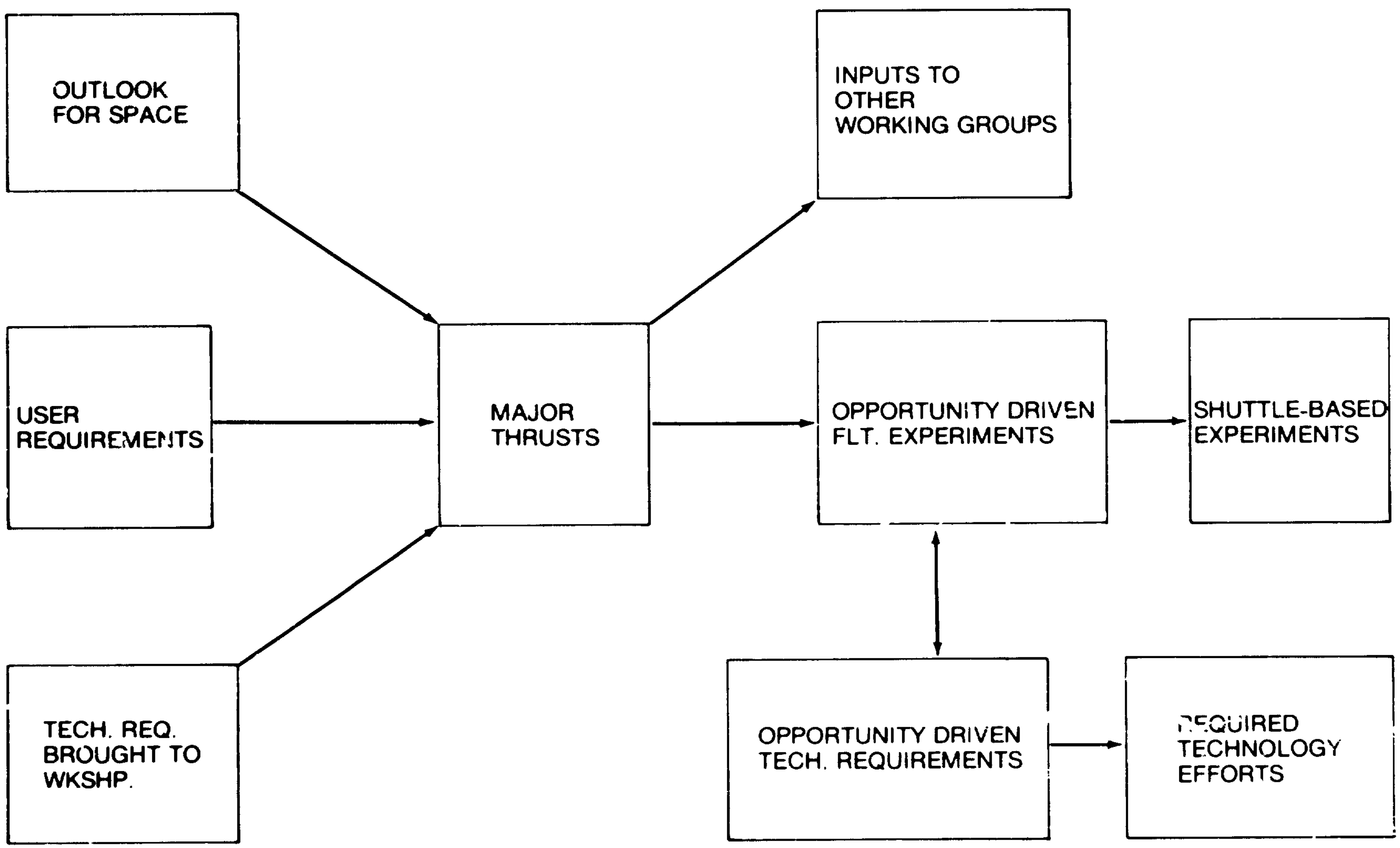


Fig. 3: LIFE SUPPORT WORKING GROUP



APPENDIX A

PARTICIPANTS

STEERING COMMITTEE

Robert E. Smylie, OAST, Chairman
William C. Hayes, Jr., OAST, Vice-Chairman
Paul N. Herr, OAST, Executive Secretary
Frederick J. DeMeritte, OAST
George C. Deutsch, OAST
Alfred Gessow, OAST
Gerald Kayten, OAST
Peter R. Kurzhals, OAST
James Lazar, OAST
Dan C. Popma, OSF
Stanley R. Sadin, OAST
Francis C. Schwenk, OAST
Gene L. Goglia, Old Dominion University

CENTER COORDINATORS

Mervin G. Ault, Lewis Research Center
Melvin E. Burke, Flight Research Center
Pat Denardo, Ames Research Center
Paul E. Fitzgerald, Jr., Johnson Space Center
W. Ray Hook, Langley Research Center
Thomas Vrebalovich, Jet Propulsion Laboratory
Leonard S. Yarbrough, Marshall Space Flight Center

BASIC RESEARCH

Kenneth W. Billman, Ames Research Center, Chairman
Tom H. Cochran, Lewis Research Center
Edmund J. Conway, Langley Research Center
Melvin M. Saffren, Jet Propulsion Laboratory
Francis C. Schwenk, OAST
Eugene W. Urban, Marshall Space Flight Center
Ping Tcheng, Old Dominion University

DATA PROCESSING AND TRANSFER

Jack G. Sheppard, Chairman, Johnson Space Center
Richard D. Alberts, Air Force Avionics Laboratory
Harold Alsberg, OAST
James W. Bagwell, Lewis Research Center
Robert H. Brown, Johnson Space Center
Art Griffin, Kennedy Space Center
William M. Howle, Jr., Langley Research Center
Ronald M. Muller, Goddard Space Flight Center
Charles E. Pontious, OAST
Edgar M. Van Vleck, Ames Research Center
Gabriel R. Wallace, Marshall Space Flight Center
William M. Whitney, Jet Propulsion Laboratory
Muralidhara Varanasi, Old Dominion University

ENTRY

Phillip R. Nachtsheim, Chairman, Ames Research Center
Peter A. Cerreta, OAST
James J. Gangler, OAST
Floyd R. Livingston, Jet Propulsion Laboratory
Paul M. Siemers, Langley Research Center
Gerald D. Walberg, Langley Research Center
William J. Breedlove, Old Dominion University

LIFE SUPPORT

Phillip D. Quattrone, Chairman, Ames Research Center
Oscar K. Houck, Johnson Space Center
J. Dwight Johnston, Marshall Space Flight Center
Dan C. Popma, OSF
Michael W. Hyer, Old Dominion University
Muralidhara Varanasi, Old Dominion University

MATERIALS

Robert A. Signorelli, Chairman, Lewis Research Center
James J. Gangler, OAST
William D. Klopp, Lewis Research Center
Robert Lad, Lewis Research Center
W. Barry Lisagor, Langley Research Center
Eugene C. McKannan, Marshall Space Flight Center
Howard G. Nelson, Ames Research Center
Charles H. Savage, Jet Propulsion Laboratory
Charles E. Vest, Goddard Space Flight Center
Stephen G. Cupschalk, Old Dominion University

NAVIGATION, GUIDANCE AND CONTROL

William E. Bachman, Chairman, Jet Propulsion Laboratory
Kirk M. Dawson, Jet Propulsion Laboratory
William B. Gevarter, OAST
Harold J. Gordon, Jet Propulsion Laboratory
William D. Hibbard, Goddard Space Flight Center
William E. Howell, Langley Research Center
J. Dwight Johnston, Marshall Space Flight Center
James P. Murphy, Ames Research Center
Ping Tcheng, Old Dominion University
William J. Breedlove, Old Dominion University

POWER

Charles B. Graff, Chairman, Marshall Space Flight Center
John C. Becker, Jet Propulsion Laboratory
Daniel T. Bernatowicz, Lewis Research Center
Ernst M. Cohn, OAST
William R. Dusenbury, Johnson Space Center
James A. Hutchby, Langley Research Center
Rodney M. Knight, Lewis Research Center
Robert P. Migra, Lewis Research Center
James F. Morris, Lewis Research Center
Arthur Obenschain, Goddard Space Flight Center
Surendra N. Tiwari, Old Dominion University

PROPULSION

Duane F. Dipprey, Chairman, Jet Propulsion Laboratory
David C. Byers, Lewis Research Center
Warren L. Dowler, Jet Propulsion Laboratory
John W. Gregory, Lewis Research Center
James Lazar, OAST
William C. Lund, Goddard Space Flight Center
James F. Morris, Lewis Research Center
Robert J. Richmond, Marshall Space Flight Center
John W. Stearns, Jet Propulsion Laboratory
Frank Stephenson, OAST
Donald L. Young, Jet Propulsion Laboratory
Robert L. Ash, Old Dominion University

SENSING AND DATA ACQUISTION

Robert N. Parker, Chairman, Langley Research Center
Adarsh Deepak, Old Dominion University
Robert V. Hess, Langley Research Center
Philip R. Maloney, Johnson Space Center
Harry G. McCain, Goddard Space Flight Center
Stewart L. Ocheltree, Langley Research Center
William T. Powers, Marshall Space Flight Center
Bernard Rubin, OAST
Herbert G. Trostle, Jet Propulsion Laboratory
John Vorreiter, OAST
Surrendra N. Tiwari, Old Dominion University

STRUCTURES AND DYNAMICS

Edwin T. Kruszewski, Chairman, Langley Research Center
Kenneth S. Bush, Langley Research Center
James F. Faddoul, Lewis Research Center
Douglas A. Gilstad, OAST
Brantley R. Hanks, Langley Research Center
Charles E. Lifer, Marshall Space Flight Center
Dennis K. McCarthy, Goddard Space Flight Center
Marc R. Trubert, Jet Propulsion Laboratory
Michael W. Hyer, Old Dominion University

THERMAL CONTROL

William F. Carroll, Chairman, Jet Propulsion Laboratory
Bernard G. Achhammer, OAST
James R. Barber, Lewis Research Center
Larry N. Dumas, Jet Propulsion Laboratory
John P. Kirkpatrick, Ames Research Center
Charles E. Lifer, Marshall Space Flight Center
James F. Morris, Lewis Research Center
Standord Ollendorf, Goddard Space Flight Center
Wayne S. Slemp, Langley Research Center
Robert L. Ash, Old Dominion University

USERS

Dudley G. McConnell, Chairman, OA
Wendell G. Ayers, Langley Research Center
James R. Edberg, Jet Propulsion Laboratory
Bill Gilbreath, OAST
Charles L. Korb, Goddard Space Flight Center
Dan C. Popma, OSF
Jesco H. VonPuttkamer, OSF
Charles W. Quantock, Marshall Space Flight Center
Edward A. Wolff, Goddard Space Flight Center
Leonard S. Yarbrough, Marshall Space Flight Center

PROGRAM SUPPORT

Charles I. Tynan, Jr., Chairman, Langley Research Center
Edward A. Gabris, OAST
Paul N. Herr, OAST
W. Ray Hook, Langley Research Center
Carmen A. Lucci, Langley Research Center
Robert S. Osborne, Langley Research Center
Melvyn Savage, OSF
Wilford E. Sivertson, Langley Research Center
Curtis Brooks, Old Dominion University

OLD DOMINION UNIVERSITY

Gene L. Goglia, Principal Investigator
Robert L. Ash
William J. Breedlove
Curtis Brooks
Stephen G. Cupschalk
Michael W. Hyer
Ping Tcheng
Surendra N. Tiwari
Muralidhara Varanasi

APPENDIX B

SOURCE DOCUMENTS

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Space Shuttle Brochure

Advanced Technolgoy Laboratory (ATL) Brochure

Long Duration Exposure Facility (LDEF) Brochure

Scout Brochure

APPENDIX C

PRESENTATION AGENDA

WELCOME, WORKSHOP BACKGROUND AND OBJECTIVES . . . . R.E. SMYLIE

AGENCY PROGRAM OVERVIEW (Keynote Address) . . . . J.E. NAUGLE

OAST PROGRAM OVERVIEW . . . . R.E. SMYLIE

OUTLOOK FOR SPACE

- OVERVIEW AND EXTRA-TERRESTRIAL ACTIVITIES. . . . . P.E. CULBERTSON
- TERRESTRIAL ACTIVITIES . . . . R.O. PILAND
- TECHNOLOGY FORECASTING . . . . W.M. WHITNEY

OAST TECHNOLGOY PLANNING

- OAST PLANNING AND SUPPORTING STUDIES . . . . S.R. SADIN
- OUTLOOK FOR SPACE TECHNOLOGY/MISSION MODEL . . . . J.D. BURKE
- OUTLOOK FOR SPACE/FLIGHT EXPERIMENT OPPORTUNITIES . . . . R.L. CHASE
- SHUTTLE PAYLOAD TECHNOLOGY/FLIGHT OPPORTUNITIES . . . . . H.M. IKERD
- DECISION ANALYSIS APPLIED TO TEST OPTIONS . . . . J. SCRATT

TECHNOLOGY USER'S NEEDS AND PRIORITIES

- OFFICE OF APPLICATIONS . . . . D. G. McCONNELL
- OFFICE OF SPACE FLIGHT . . . . J. VonPUTTKAMER
- OFFICE OF SPACE SCIENCE .E.A. WOLFF

SPACE TRANSPORTATION SYSTEM CAPABILITIES, LIMITATIONS AND RESOURCES

- INTRODUCTION . . . . P.E. CULBERTSON
- SPACE SHUTTLE SYSTEM .J. HAMMERSMITH
- TUG, IUS, and OTHER STAGES . . . . M.D. KITCHENS
- SPACELAB . . . . W. E. MILLER, JR.
- ADVANCED TECHNOLOGY LABORATORY (ATL) . . . . .W.E. SIVERTSON
- LONG DURATION EXPOSURE FACILITY (LDEF) AND SCOUT . . . . .R.S. OSBORNE